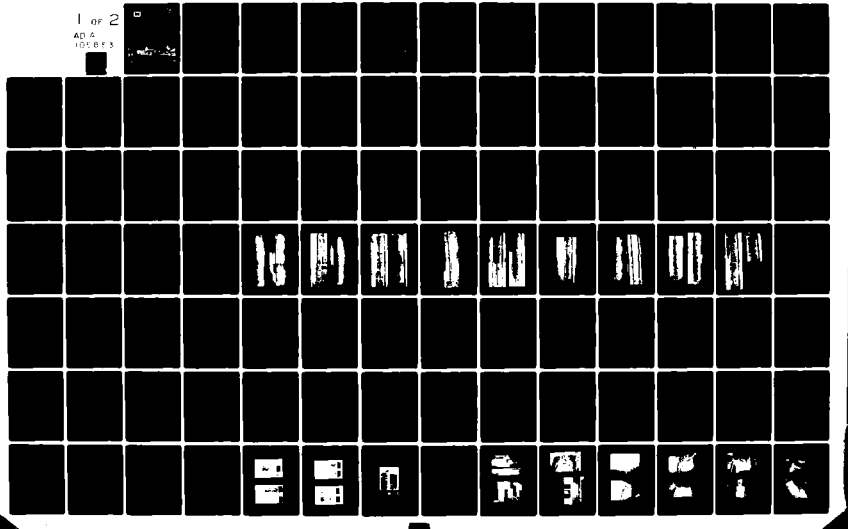
AD-A105 653 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/2
CONDITION SURVEY, REPAIR AND REHABILITATION, LOCK AND DAM NUMBE--ETC(U)
AUG 81 R L STOWE, H T THORNTON
UNCLASSIFIED WES/MP/SL-81-21 NL



MISCELLANEOUS PAPER SL-81-21

CONDITION SURVEY
REPAIR AND REHABILITATION
LOCK AND DAM NO. 24, MISSISSIPPI RIVER

by

Richard L. Stowe, Henry T. Thornton, Jr.

Structures Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

August 1981
Final Report

Prepared for U. S. Army Engineer District, St. Louis
210 Tucker Blvd., North, St. Louis Mo. 63101

Destroy this report when no longer needed. Do not return it to the originator.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Miscellaneous Paper SL-81-21
2. GOVT ACCESSION NO.: AD-A105653
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): CONDITION SURVEY, REPAIR AND REHABILITATION, LOCK AND DAM NO. 24, MISSISSIPPI RIVER.
5. TYPE OF REPORT & PERIOD COVERED: Final report.
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Richard L. Stowe, Henry T. Thornton, Jr.
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station, Structures Laboratory, P. O. Box 631, Vicksburg, Miss. 39180
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Engineer District, St. Louis, 210 Tucker Blvd., North, St. Louis, Mo. 63101
12. REPORT DATE: Aug [redacted] 81
13. NUMBER OF PAGES: 137
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Concrete dams
Concrete deterioration
Laboratory tests
Lock and Dam No. 24, Mississippi River
Locks (Waterways)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A condition survey of the concrete was performed at Lock and Dam No. 24 on the Mississippi River. Field studies indicated that 32 percent of the concrete bridge support columns are moderately to severely deteriorated, 48 percent are slightly deteriorated, and 20 percent show no sign of damage. A small zone of concrete downstream of the trunnion shafts is severely deteriorated. Cores were recovered from areas representative of the different degrees of damaged concrete and examined and tested in the laboratory. Some of the

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

cores were extensively damaged by cycles of freezing and thawing to depths of 2 ft. Compressive strengths of the cores ranged from 2010 to 9770 psi. The minimum remaining compressive strength in the columns is estimated at 1000 psi. Techniques for removal and repair of damaged concrete are recommended. Removal of concrete by water jet is suggested.

PREFACE

The work described herein was performed for the U. S. Army Engineer District, St. Louis (SLD), by personnel of the U. S. Army Engineer Waterways Experiment Station (WES). The work was authorized by DA Form 2544 No. ED 80-75 dated 3 September 1980, No. ED 80-75 R1 dated 25 September 1980, and ED 80-75 R2 dated 18 November 1980.

The testing program was accomplished under the direction of Mr. Bryant Mather, Chief of the Structures Laboratory (SL), WES, and Mr. John M. Scanlon, Jr., Chief of the Concrete Technology Division (CTD), SL. Mr. H. T. Thornton, CTD, was Project Leader and was assisted in performing the laboratory work by Messrs. R. L. Stowe, F. S. Stewart, and G. S. Wong and Mrs. Joyce C. Alvin, all of CTD. The core drilling was conducted by personnel of the Geotechnical Laboratory (GL), WES, under the direction of Mr. Mark A. Vispi. SLD personnel furnished the photographs in Appendix D. This report was largely written by Messrs. Stowe and Thornton; Messrs. Wong and J. E. McDonald, CTD, contributed portions.

Directors of WES during the conduct of the investigation and the publication of this report were COL N. P. Conover, CE, and COL T. C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	0.0254	metres
miles (U. S. statute)	1.609344	kilometres
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

CONDITION SURVEY

REPAIR AND REHABILITATION

LOCK AND DAM NO. 24, MISSISSIPPI RIVER

PART I: INTRODUCTION

Location and General Description

1. Lock and Dam No. 24, Mississippi River, is situated at Clarksville, Missouri, 93.5 miles* upstream from St. Louis, and 273.5 miles above the mouth of the Ohio River. It is close to the Missouri shore at the base of a high, steep hill. The project consists of a main lock and upper gate bay of an auxiliary lock; a dam containing a movable section of 15 tainter gates; and a fixed submersible stone-covered earth dike reaching to the Sny Island Drainage and Levee District.

2. The regulating portion of the dam consists of fifteen 80-ft-wide tainter gates. Dam piers are pile supported. The submersible dike extending from the storage yard to the Illinois shore is constructed with a core of steel pile cells covered with stone and slush concrete.

Background

3. In 1973, ultrasonic pulse velocity measurements were made through selected piers of Locks and Dams No. 24 and 25. The results of these tests were reported to the St. Louis District (SLD) by letter dated 29 October 1973, subject, "Results of Soniscope Survey of Lock and Dam No. 24 and 25, Mississippi River." In 1976,[1] the presence of alkali-silica reaction in concrete from an intermediate wall of Lock and Dam No. 24 was established by the examination of 6-in. and 4-in.-diameter cores. The concrete cores were from an area of undeteriorated concrete. In October 1978, five NX (2-1/8-in. diameter) concrete cores were received from the U. S. Army Engineer District, St. Louis, for examination.

---

* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 3.

These cores were taken from the downstream portions of three piers in the dam of Lock and Dam No. 24. The cores were in fragments with the longest intact piece of core being about 2-1/2 in. Results of the examination of these cores were reported in December 1978.[2]

4. In September 1979 members of the Structures Laboratory, Waterways Experiment Station (SL, WES), performed a more extensive ultrasonic pulse velocity investigation of the concrete portion of the dam structure at Lock and Dam No. 24. This investigation included selected concrete columns that support the service bridge as well as piers No. 2 through 15. The objectives of this investigation were to determine, by nondestructive means, the extent and severity of cracking near the trunnion shafts on the downstream portions of the piers and to determine the extent of cracking in the columns. The results of this investigation were reported in WES Miscellaneous Paper SL-80-2.[3]

Objectives

5. The objectives of the investigation reported herein were to:

   a. Determine the effect of water intrusion (if any) on the reinforcing steel and tainter gate anchorage steel in the area around the trunnion shaft. Pier No. 9 was selected to be examined.

   b. Determine the remaining compressive strength of the concrete in the piers and the service bridge support columns.

   c. Determine the extent, severity, and cause of the concrete deterioration in the piers and support columns.

   d. Determine the location, extent, and cause of any structural cracks.

   e. Suggest repair materials and repair methods.

Scope

6. The investigation included:

   a. Preliminary engineering study.

      (1) Visual inspection of dam.

      (2) Collection and review of all available records and data.

b. Drilling and excavation of concrete.

c. Laboratory testing and analysis of concrete core.

PART II: PRELIMINARY ENGINEERING STUDY

Review of Reports and Drawings

7. All available reports, records, and drawings pertinent to this study were collected and reviewed. The items available for review included construction drawings and photographs, postconstruction concrete reports, Periodic Inspection Reports including instrumentation data and analysis, concrete core test and examination reports, a report of field ultrasonic velocity measurements, and boring logs. Specific references to these reports and drawings are made in appropriate parts of this report.

Inspection of Dam

8. Personnel from the WES, SLD, and Lock and Dam No. 24 inspected the dam to observe the extent of damaged concrete on exposed surfaces, locate any structural cracks, obtain information from maintenance, repair, and operational records, and to talk with lock personnel. Persons inspecting the dam are given in Table 1. Photographs showing typical damaged concrete are presented in Appendix A, pages A2 through A5.

9. The piers and the service bridge support columns of the dam were examined to ascertain the physical condition of the exposed concrete surfaces. As a result of the examination, the exposed concrete was classified into five categories based upon crack width and frequency and the amount of exudation present. The "Concrete Condition" terms were established by the authors. The crack width ranges are given in the "Guide for Making a Condition Survey of Concrete in Service;" see Reference 4. The different concrete conditions are tabulated below:

Concrete Condition	Description
"OK"	No signs of deterioration
Very light	Local cracks (infrequent), closed hairline, one per 3- by 3-ft area, slight exudation

Concrete Condition	Description
Light	Local cracks (infrequent), fine (<1 mm, 0.04 in.), one per 3- by 3-ft area, slight exudation
Moderate	Zone cracking, medium (1 to 2 mm, 0.04 to 0.08 in.), one crack every 3 to 4 in., heavy exudation covering 50 percent of zone
Severe	Zone cracking, medium to wide (wide >2 mm, 0.08 in.), one crack every 2 to 3 in. apart, heavy exudation covering ~75 percent of zone.

10. Zones of damage were sketched (to scale) for the upstream and the downstream surfaces of the bridge columns. If a small zone of damage exists, then the whole bridge column was classified based upon the condition of the small zone. Some damaged zones extended over a few square feet while others over tens of square feet. No sketches were made for the zones of damaged concrete just downstream of the trunnion shafts in the piers. The exterior and interior extent of concrete damage in the piers and bridge columns is presented and discussed in Part V of this report.

11. A number of structural cracks were observed in the bridge columns on piers No. 9 and No. 16. The extent and width of structural cracks were mapped. For purposes of this report structural cracks are defined as those cracks caused by external applied loads. The extent of the structural cracks is presented in Part VI of this report.

12. Mr. Dan Buckley, Lockmaster at Lock and Dam No. 24, was on the inspection team. He explained to the team the difficulty encountered, on a number of occasions, in passing thick ice over a couple of the tainter gates. The ice would build up behind the gates. When it broke loose and was passing the gate, he observed a trunnion shaft oscillating due to the vibrations caused by ice hitting the piers and the gates. He also related that the townspeople, adjacent to the lock, complained of inordinate vibrations on occasions when thick ice was being passed; windows rattling and vibration felt through the floors of houses.

13. In addition to the ice problem, Mr. Buckley told us that the tainter gates are now not lowered to their design depth. When they are lowered to their maximum depth, inordinate vibrations result due to the applied water loads.

PART III: DRILLING AND EXCAVATION

Drilling

14. Information gathered during the inspection of the dam indicated that 32 percent of the service bridge support columns (total of 64) are moderately to severely deteriorated; 48 percent of the columns are very light to lightly deteriorated; and 20 percent have no signs of deterioration. Columns representative of the different concrete conditions were drilled. Six of the severely and three of the moderately deteriorated columns had short horizontal borings placed in them. Four columns showing no evidence of deterioration had borings placed in each of them. Borings in the columns were drilled through to the opposite side.

15. Three of the piers were drilled to obtain information on the quality of the concrete with depth. Vertical borings were located in those piers where nondestructive testing (Reference 3) indicated poor concrete and where survey data indicated the greatest amount of settlement and downstream movement of the piers.[5] The measured settlement and downstream movement are relatively small, 0.03 ft and 0.06 ft, respectively. In general, the piers indicating the greatest movement also indicate the greatest settlement. Short horizontal borings were also placed in the piers. Borings in the piers were drilled in the vicinity of the trunnion shafts. See Plate 1 for general boring locations; specific boring locations are given on plates presented in Part V of this report.

16. Boring designations appearing on Plate 1 are explained as follows; S WES P04.1 and S WES C02.2N are used as examples: S, sponsor (St. Louis District); WES, drilling agency (Waterways Experiment Station); P&C, for pier and column; first two numbers for pier numbers; third number is column number 1 through 4; and last letter represents north, east, south, or west face of a column. See Plate 1 for order of column numbers.

17. A total of 4 vertical borings and 21 horizontal borings were drilled. A total of 161 ft of core was recovered. Core recovery was

99 percent. See Table 2 for detailed boring information. The following information is presented for each boring; the direction of the boring, the location, the elevation of the top of boring, the elevation bottom of boring, depth of horizontal borings, and the date when the boring was started. Core logs are presented in Appendix B.

18. A WES drill crew conducted the drilling at Lock and Dam No. 24. Drilling equipment consisted of an Acker Toredo Mark II and a Sprage and Henwood skid-mounted rotary drill rig. A Diamond Core Drill Manufacturers Association standard 4-in. by 5-1/2-in. double tube swivel tube core barrel and 5-7/8- by 6-1/8-in. thin wall barrel were used with diamond bits to obtain the concrete core. Access to the dam was by a marine floating plant supplied by the SLD; once on the dam, the crane on top of structure was used to position and move drill equipment. The crane was operated by a WES operator. Continuous samples were obtained in all borings. A Concord portable electric drill rig was used in drilling horizontal borings in the columns.

19. All borings were backfilled with concrete using packaged dry combined materials. To each 50 lb of materials was added 10 lb of portland cement. To each 60 lb of materials, enough water was added to make a stiff mixture. Prior to adding the required water to the materials, 1 ml of air-entraining admixture was mixed in the water. After a 24-hr period, the crown area of the backfilled horizontal borings in the columns were sealed. A slightly expanding cement grout (aluminum powder was added to cement) was pumped into and along the crown area of the borings. The sealing operation was necessary due to the shrinkage of the concrete away from the crown area of the horizontally drilled hole. It was directed that all borings in the columns be backfilled and sealed before the crane was allowed to pass over those columns that were drilled.

Excavation Around Trunnion Shaft

20. Concrete from around the trunnion shaft in pier No. 9 was excavated to expose a small portion of the tainter gate anchorage steel. This work was done to reveal the physical condition of the anchorage

steel. With evidence of cracked concrete and impounding water in the area of the trunnion shaft, there was concern that rusting of the anchorage steel had reduced the steel's cross section. See Plate 2 for a cross section of the zone examined. Photographs No. 8 through 13, Appendix A, show the excavated zone.

21. The concrete was removed from around the anchorage steel using a hand held air-hammer. The first foot of concrete was removed without great difficulty as compared to the remaining 1-1/2 ft. The concrete was hard and tough to remove. Occasional cracks were encountered that were lightly stained; the staining resulted from infiltrating rain water.

22. A plastic cork, as described on the original plans, was found bonded to the anchorage steel. It was intact and had to be torn away from the steel except near the top of the pier. The area crossed hatched in Plate 2 indicates the zone of rusting that was detected. The rusting reduced the steel cross section about 1/64 in. on the trunnion collar; original thickness of collar is 2 in. The damage to the steel is considered insignificant. See photographs No. 11, 12, and 13 (Appendix A) for rusted zone.

23. An asphaltic bonding material was applied to the anchorage steel prior to backfilling the excavated hole. The hole was cleaned of loose material, air blown, and backfilled with air-entrained concrete. The concrete was vibrated in 1-ft lifts, finished, and cured.

PART IV: TEST SPECIMENS AND TEST PROCEDURES

Cores Received

24. Concrete core from 25 borings was received at the WES. Shipment of the core was handled by the WES drill crew. Cores were shipped in sawdust lined core boxes. Upon receipt of the core, it was inspected for damage; there was no damage due to handling and shipping. The core that was not selected for testing remains at the WES; it will be discarded or shipped to the SLD after completion of the investigation.

Selection of Test Specimens

25. A detailed visual examination of all the core was made to assist in the selection of representative test specimens. The examination was further used to verify the depth of damaged concrete in the core. Test specimens were selected from the top, middle, and bottom portions of all the vertical cores and on those horizontal drilled cores where core was intact and could be tested. Many test specimens contained portions of damaged concrete; i.e., horizontal and inclined cracks and weathered concrete. Some specimens were pieced back together for compressive strength testing; e.g., on some cores where an inclined or horizontal crack caused separation of the core, pieces were placed back together and tested. Nominal 6-in.-diameter by 12-in.-long specimens were used for the various physical property tests. Test specimen locations on the cores are given on appropriate drawings and sketches in Part V of this report.

26. After examining the core in detail, a comparison between the condition of the core and the condition of the in-place surface concrete was made. The core and in-place surface concrete compared quite well; i.e., where severe deteriorated core exists, severe deteriorated in-place surface concrete existed. This comparison enables one to say that other columns with the same classification ("OK", moderate, and severe) would likely contain internal concrete similar to the columns that were cored.

This information will be helpful if the damaged concrete is replaced.

27. Portions of concrete from five cores were selected for detailed petrographic examination. A general description of the 6-in.-diameter concrete cores is as follows:

Field Identification No.	Description
S WES-C16.2 N-80	Horizontal core into badly deteriorated concrete, from column
S WES-C16.3 E-80	Horizontal core into moderately deteriorated concrete, from column
S WES-C13.2 N	Horizontal core into good concrete, from column
S WES-P04.1	Vertical core into good concrete, from pier
S WES-P09.1	Vertical core into good concrete, from pier

Physical Property Test Procedures and Petrographic Examination

28. The physical property tests were conducted in accordance with the appropriate test methods tabulated below:

Property	Test Method
Unit Weight (As Received), γ_m	CRD-C 107-69[6]
Water Content, w	CRD-C 113-80 (ASTM C 566-78)
Pulse Velocity, V_p	CRD-C 51-72 (ASTM C 597-687)
Compressive Strength, q_u	CRD-C 27-78 (ASTM C 42-77)
Elastic Modulus, E	CRD-C 19-75 (ASTM C 469-65)
Poisson's Ratio, ν	CRD-C 19-75 (ASTM C 469-65)

29. Applicable portions of CRD-C 57-78 (ASTM C 856-77) were used in conducting a petrographic examination on representative concrete core; see Appendix B for specific works accomplished.

PART V: RESULTS AND DISCUSSION

Petrographic Examination

30. The results of the petrographic examination of the concrete cores are presented in detail in Appendix C. A brief summary is presented in the following paragraphs.

31. The concrete is not air entrained. The concrete contains gravel and sand of mixed composition; maximum size aggregate is about 1-1/2 in. Coarse aggregate consists of sandstone, quartz, chert, carbonate rock particles, igneous rock particles, and some particles of ironstone. Chalcedony in the chert particles was identified as the common reactive material in the concrete. This finding is similar to the observations made in previous reports.[1,2]

32. The major deterioration consists of parallel to subparallel cracking occurring parallel to the formed core surfaces. This type of cracking is characteristic of freezing and thawing action. The concrete tends to be saturated with white alkali-silica gel. The alkali-silica reaction contributed to the concrete cracking. The gel is present as coatings (exudation) on cracks and exterior core surfaces. The calcium hydroxide has carbonated to calcite on exposed surfaces.

33. The black coating observed on a cracked core surface at about 12.5 ft of core S WES-P04.1 is a pliable tar-like substance; it appears to be a bond-breaker material that was applied to the surface examined or that flowed from somewhere else to its present location.

34. It is not possible to determine how much of the damage in the cores was due to freezing and thawing and alkali-silica reaction. An additional mechanism could have caused some of the observed cracking or initiated cracking which allowed freezing and thawing and alkali-silica reaction to begin.

Extent of Damaged Concrete

35. The extent of concrete damage was ascertained from the field investigation and the detailed examination of the core. The photographs of cores presented in Plates 3 through 11 are typical examples of three different concrete conditions, the "OK" (no deterioration), moderate, and severe deterioration. Cross section and orthographic projection drawings were made to show the extent of damaged concrete in the downstream portions of the piers and in the bridge columns; see Plates 12 through 31.

36. There is a distinct difference in the physical condition of the cores representing the "OK" (no deterioration) and the moderately and severely deteriorated concrete; view Plates 3 through 13. The "OK" cores represent sound concrete with an occasional natural break. The term natural break is used to describe a break in the concrete when the mechanism that caused the break is unknown. The cores representing the moderately and severely deteriorated concrete show clear evidence of damage by frost action, i.e., subparallel cracks to the formed surfaces (end of cores). Note that the majority of the damaged concrete is near the formed surfaces; there is little or no damage towards the middle of the core. For all practical purposes the core representing the moderate and severe class concrete can be grouped together when considering their physical condition. Cores from both classifications contain about the same amount of damaged concrete. Core S WES C09.2N is of poor quality; however, it looks worse as a core than the concrete it represents in-place. The broken condition of the core is due to frost action, alkali-silica reaction, and core barrel blockage. The concrete was cracked in place as evidenced by its weathered nature, but broken somewhat during drilling and upon removal from the core barrel.

Piers

37. Cross sections for the three piers (No. 4, No. 9, and No. 15) in which vertical and horizontal borings were drilled are presented in Plates 12, 13, and 14. A small zone of severely deteriorated concrete exists below and downstream of the trunnion shaft for the full 10-ft

width of the pier. The zone extends from station 99.75 ft to a maximum depth at station 98.5 ft in pier No. 4. In pier No. 9 the zone is 0.9 ft deep and in pier No. 15 the zone is 0.4 ft deep. The depth of the zone could be deeper in the piers not drilled. Major cracks in the core recovered from the piers are presented on these three cross sections. The cracks help to explain some of the "no readings, NR," in the downstream portions of the piers.[3] Plate 13b shows the location of the ultrasonic velocity measurements taken on pier No. 9 and the cracks observed in borings S WES P09.1 and P09.3. The uppermost crack in P09.1 could account for the "no reading" at stations No. 6 and 7. This plate also indicates that other "no readings" are accounted for by the anchorage steel; the interface between the concrete, plastic cork, and the steel would attenuate the transmitted pulse. The in-place velocities obtained by Thornton[3] compare well with the velocities recorded on the laboratory test specimens.

38. The physical properties from the pieces of core tested are presented on Plates 12 through 14. Stress-strain curves for selected core from the piers are presented in Plates 15 through 18. Circled numbers adjacent to the borings indicate the location (elevation) from which a test specimen was taken. Like circled numbers, on-line with the various physical properties, represent those numbers adjacent to the cores. The physical properties obtained on the core recovered from the three piers indicate good quality concrete throughout the downstream portion of the piers. The lowest strength is 5840 psi on the uppermost piece of concrete from S WES P15.1. There is no reason to suspect that interior concrete in the other piers has less quality than the concrete tested during this investigation. The concrete in the piers is sound although a few natural breaks are present. These breaks could be sealed by injecting a bonding agent into the breaks.

Columns

39. The extent of damaged concrete in the bridge columns is presented in Plates 19 through 35. Physical property test results for core taken from the columns is included on appropriate plates. The surface extent and depth of damaged concrete can be readily seen on Plates 19

through 35. For those columns where borings were made, the actual depth of damaged concrete is shown. Some of the backsides of the columns (opposite side of columns from the side the drill entered) contained damaged concrete; it is shown where it occurs. The average depth of damaged concrete on the outside in the moderately and severely deteriorated columns is 1 ft. For the moderately and severely deteriorated columns that were not drilled, the 1-ft depth of damaged concrete is believed to exist and is shown. The average depth of damaged concrete on the backside for both the moderate and severe classificated columns is 0.25 ft. The middle of the columns do not show freeze-thaw damage. The following tabulation summarizes the depth of damaged concrete in the columns. The greatest amount of damaged concrete was recovered from the downstream and the upstream faces of the columns.

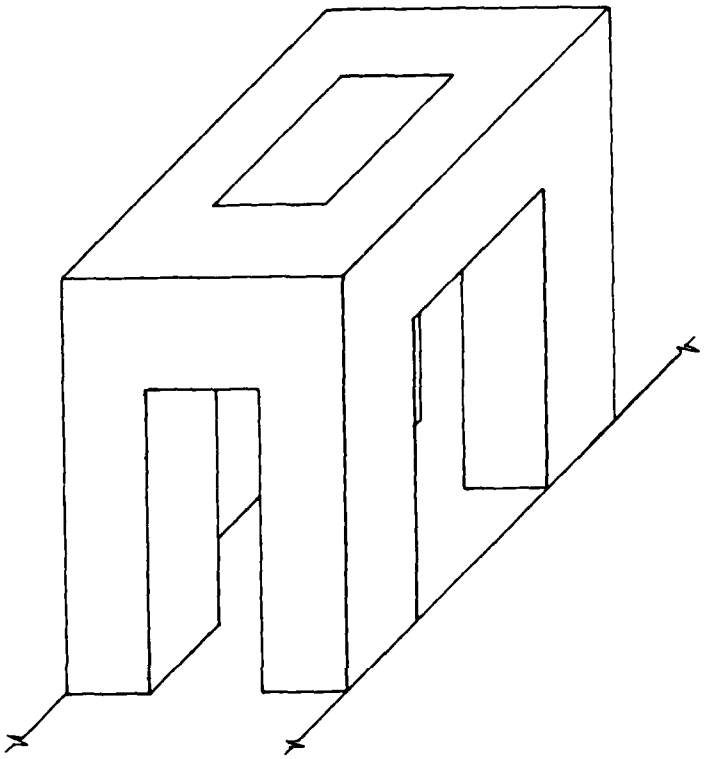
Core Location	Depth of Damage	
	Moderate Deterioration	Severe Deterioration
Outside	1 ft (0.7 ft - 1.7 ft)	1 ft (0.6 ft - 2.0 ft)
Middle	Slight	None
Backside	0.2 ft	0.3 ft

The plan cross sectional area of a column is 10.5 ft^2. Considering the average depth of damage for the full width of a column, the damaged concrete occupies 3.75 ft^2, there remains within a column 6.75 ft^2 of undamaged concrete.

Physical Property Tests

40. A summary of the physical properties for the "OK", moderate, and severely deteriorated concrete is presented in Figures 1 through 3. Stress-strain curves for selected core taken from the columns are presented in Plates 36 through 43. Some of the compression test specimens were selected to include the damaged concrete; some of the outside and the backside specimens contain damaged concrete. In several cases core that was separated by the action of freezing and thawing was put back together and tested in compression. See photographs in Plates 44 through

"OK" (NO DETERIORATION), COLUMNS



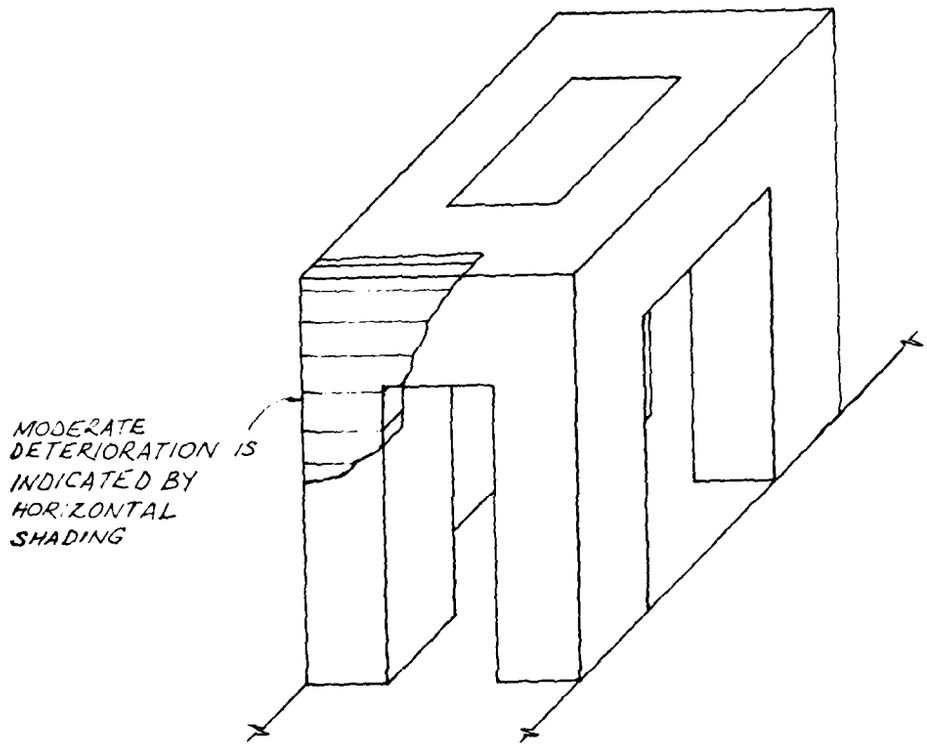
AVERAGE PROPERTIES with RANGES

TEST	OUTSIDE	MIDDLE	BACKSIDE
γ, lb/ft^3	157.5	152.5 (152.2-152.8)	158.0
w, pct	4.8	4.4	4.4
V_p, fps	15,333	15,665 (15,134-16,196)	15,073
q_u, psi	9,770	9,080 (8,870-9,770)	10,310
E, $\times 10^6$ psi	5.04	5.55	5.34
ν,	0.25	0.19	0.18

	Lowest	Average	Highest
Original concrete strength, Class B	4,710 psi	5,930 psi	7,040 psi

Figure 1. Average physical properties with ranges for the OK class concrete

MODERATE DETERIORATION, COLUMNS



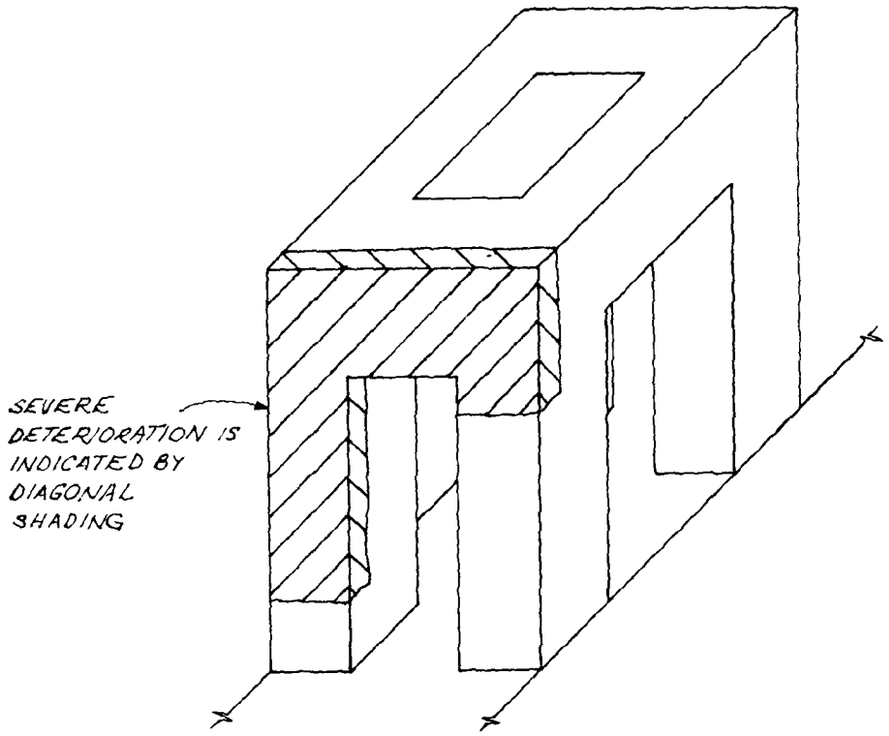
AVERAGE PROPERTIES with RANGES

TEST	OUTSIDE	MIDDLE	BACKSIDE
γ, lb/ft^3	156.3 (154.7-160.8)	151 (150.2-152.6)	
w, pct	5.3 (5.0-5.7)	5.2 (5.1-5.6)	
V_p, fps	11,995 (10,757-14,178)	13,140 (12,125-13,555)	
q_u, psi	6,630 (6,490-6,720)	7,650 (7,350-8,250)	
E, $\times 10^6$ psi	1.57 (1.42-1.72)	3.97 (2.42-3.52)	
ν,	0.16 (0.14-0.17)	0.16 (0.14-0.18)	

	Lowest	Average	Highest
Original concrete strength, Class B	4,710 psi	5,930 psi	7,040 psi

Figure 2. Average physical properties with ranges for the moderate class concrete

SEVERE DETERIORATION, COLUMNS



AVERAGE PROPERTIES with RANGES

TEST	OUTSIDE	MIDDLE	BACKSIDE
γ, pcf	152.5 (148.7-160.3)	150.0 (146.5-154.3)	150.7 (147.8-154.6)
w, pcf	5.6 (4.9 - 6.2)	5.4 (4.4 - 6.4)	5.4 (5.1 - 5.7)
v_p, fps	4,381 (2,774-8,924)	11,961 (11,111-14,303)	9,730 (9,090-10,707)
f_s, psi	2,760 (2,070-5450)	4,700 (3,080-6,050)	3,770 (2010-5750)
E, $\times 10^6$ psi	0.21 (0.18-0.25)	0.85 (0.38-1.50)	0.28 (0.20-0.36)
ν,			

	Lowest	Average	Highest
Original concrete strength, Class B	4,710 psi	5,930 psi	7,040 psi

Figure 3. Average physical properties with ranges for the severe class concrete

46. This procedure was used to determine the lowest remaining concrete strength in the columns. The physical properties will be discussed under the "OK", moderate, and severe classes of concrete. Strengths of cylinders that were cast during construction show the following strengths:

Lowest	Average	Highest
4710 psi	5930 psi	7040 psi

41. "OK". The densities of the outside, middle, and backside core are reasonable for sound concrete; the range is from 152.2 to 158.0 lb/ft^3; the average outside, middle, and backside densities are 157.5, 152.5, and 158.0 lb/ft^3, respectively. There is a 5- to 6-lb/ft^3 difference between the density of the near surface and middle core; the difference is attributed to, in part, the presence of reinforcing bars contained within the near surface cores. The water content of the near surface cores is about the same as the middle core. The moderate and severely deteriorated cores have a water content about 1 percent higher than the "OK" class cores. This higher water content is attributed to the presence of the damaged concrete; the cracked concrete with its increased surface area contains additional water.

42. The velocities are indicative of good quality concrete. The range in velocity is 15,073 to 16,196 ft/sec. The compressive strengths for the near surface and middle concrete are higher than the highest cylinder break obtained during construction. The range in strength is 8,870 to 10,310 psi. The modulus was figured as a secant value to 40 percent of the compressive strength. The modulus ranges from 5.04 x 10^6 psi to 5.55 x 10^6 psi. The Poisson's ratio is reasonable for good quality concrete; it ranges from 0.18 to 0.25.

43. Moderate. The outside and middle concrete show about the same difference in the average density, i.e., 5 lb/ft^3, as does the "OK" class concrete. The outside core has a greater range in density (154.7-160.8 lb/ft^3) than the middle core (150.8-152.6); again the higher density of the outside core is due to the inclusion of reinforcing bar in the outside specimens. The average outside and middle densities are

156.8 lb/ft^3 and 151.7 lb/ft^3, respectively. The average water contents are 5.3 and 5.2 percent for the outside and middle cores.

44. The difference between the average velocities of the outside and middle core is indicative of the damaged outside concrete. The outside velocity averages 11,995 ft/sec (range is 10,757-14,178 ft/sec) while the middle average is 13,140 ft/sec (range is 12,725-13,555 ft/sec). Note the smaller range of the middle cores, indicating more consistency of the concrete. The average strength of the outside and middle cores is above the average of the cylinder strengths cast during construction. The average outside and middle strengths are 6630 psi and 7650 psi. The average modulus of the outside concrete is about one-half the average modulus of the middle cores. The modulus of the moderately deteriorated concrete is considerably below the modulus of the "OK" classified concrete. The reason for the difference is probably due to the fact that the moderately deteriorated concrete contains cracks and voids that closed up under the compressive load applied to the core, resulting in larger axial deformations and hence lower modulus values. The Poisson's ratio for the outside and middle core is 0.16.

45. Severe. The average density values for the three sections of core are considered the same, 152.5, 150.0, and 150.7 lb/ft^3 for the outside, middle, and backside, respectively. The range over the full length of the cores is 146.5-160.3 lb/ft^3. The lowest density (146.5 lb/ft) was obtained for the severe class of concrete and is attributed, in part, to the damage caused by freezing-thawing and alkali-silica reaction. The greatest water content was measured on a piece of core from the severe class of concrete, i.e., 6.4 percent. The average water content for the severe class concrete is slightly above the average water content of the moderate class concrete.

46. There is no appreciable difference between the water contents in cores taken from the top of the columns to near the base of the piers. It was thought that the water contents, with depth, might be different, and if so, help to explain why some of the concrete was more heavily damaged.

47. The velocities measured on this class concrete were the lowest measured on all the cores tested. A velocity of 2,774 ft/sec was obtained on an outside core. The average outside, middle, and backside velocities are 4,381, 11,961, and 9,730 ft/sec, respectively. These relatively low values are indicative of poor quality concrete; the low velocities were anticipated considering the damaged condition of the severe class concrete. The middle cores have velocities ranging from 11,111 to 14,303 ft/sec. Again the middle cores are of better quality than the near surface core.

48. The lowest strengths were obtained from the severe class concrete; 2,070 psi for an outside core and 2,010 psi from a backside core. The lowest strength middle core is 3,080 psi; the lowest strength middle core in the other classes of concrete is 7040 psi. The average modulus values for outside and backside core are 0.21×10^6 psi and 0.28×10^6 psi. Again, large deformations of the core due to cracks and voids in the damaged concrete account for the very low modulus values. The stress-strain curves for the cores containing portions of damaged concrete show the typical stress-strain relation for cores containing open cracks; see Plates 37, 38, 40, and 42. Note the concave upwards portion of the curves which represents closure of the cracks and the voids within the specimen. Poisson's ratios are not available because lateral deformation was not measured on the severe class concrete. There was no easy way of mechanically or electrically monitoring lateral movement of the core due to its broken nature.

PART VI: SUMMARY AND RECOMMENDATIONS

Trunnion Shaft Area

49. A few fine (<1 mm, 0.04 in.) and wide (>2 mm, 0.08 in.) cracks in the concrete exist near and intersect with the trunnion shaft on all piers. Rain water has permeated the concrete along these cracks as evidenced by the presence of stains on surfaces of concrete excavated from around portions of the tainter gate anchorage steel on pier No. 9. An insignificant amount of rusting has occurred on the top 2-ft portion of the trunnion shaft collar on pier No. 9. Because all the piers have cracks in the concrete around the trunnion shafts, it is reasonable to assume that a portion of the collars on all piers is lightly rusted. The H beams of the anchorage are protected by plastic cork and are not rusted in pier No. 9. In conclusion, there is no significant damage due to rusting of the anchorage steel.

Remaining Strength of Concrete

50. The remaining compressive strength of the concrete in the piers is considered to be at least equal to the lowest compressive strength obtained on the core from the piers; that strength is 5840 psi. Except for a small zone of damaged concrete downstream of the trunnion shafts on all the piers, the interior pier concrete is sound and will serve its original intended purpose. A few natural breaks occur in the piers, but these breaks should not affect the structural integrity of the piers.

51. The remaining concrete compressive strength in the columns with the greater amount of damaged concrete is probably between 1000 and 2,000 psi; the exterior 1 ft having the 1,000-psi strength and the interior section having the 2,000-psi strength. The lowest exterior and interior core strengths were 2,010 psi and 3,080 psi, respectively. These strengths have been reduced by 1000 psi to account for a reduction

in strength. The reason for reducing the strength has to do with the difference in strength between horizontal and vertically aligned core that is cracked.

52. All cores from the columns were drilled horizontally and the cracks (closely spaced) caused by frost damage are subparallel to the core axis. Laboratory tests, from an unreported study by the principle author, of jointed concrete specimens indicate that when the joints are perpendicular to the axis of applied load, as were the cracks in the horizontally drilled core, the strength is higher than when the joints are parallel to the applied load. With closely spaced joints parallel to the applied load, eccentric loading results as individual jointed members of the specimen flex. The eccentric loads cause reduced strengths. It is not known how much the actual core strengths should be reduced; however, a 1,000-psi reduction is considered conservative.

53. Columns containing the moderately and severely deteriorated concrete that were not drilled could contain low strength concrete equal to the reduced 1,000- to 2,000-psi strengths.

Columns Adequate to Support Bridge

54. This investigation shows that the columns are not weak enough to crumble under static compressive loads. The study shows that compressive strength between 1,000 and 2,000 psi exists which is about one-half the acceptable value of the lowest original strength of 4,710 psi. Some of the concrete in the columns is now not serving its originally intended purpose. The static analysis that a SLD technical staff member conducted on 1 May 1980, "Dam 24 Service Bridge Pier," shows that 240-psi strength is required from the concrete. Based upon these computations and our strength test results, there is no problem at the present time. The concrete strength will decrease with time if the deterioration of the concrete is allowed to continue. We can not assure the adequacy of the columns due to structural movement or dynamic stresses caused by inordinate vibrations from ice loading or other conditions at the dam. It is

suggested that a dynamic stability analysis of the piers and columns be made to see if they are adequate against some critical loading conditions with the present low strength concrete.

Extent and Cause of Damaged Concrete

55. A small zone of severely deteriorated concrete exists below and downstream of the trunnion shaft for the full width of the pier; i.e., the upper part of the downstream vertical face of the piers. This condition exists on all piers. Depth of the zone is about 1.0 ft.

56. The top portions of the columns contain the greatest amount of damaged concrete; the concrete towards the bottom of the columns is sound. Trapped water on the top of the columns probably infiltrated the concrete and the freezing and thawing action caused damage near the top of the columns. With time the damaged zone has extended downwards. The downstream and upstream faces of the columns contain more damaged concrete than any other column surfaces. These column faces have more exposure to the sun and are subject to more cycles of freezing and thawing. The average depth of damage for the moderately and severely deteriorated columns is 1 ft on the upstream and downstream faces.

57. The lack of entrained air in this concrete caused the concrete to be susceptible to frost damage. The repeated freezing and thawing of the concrete while critically saturated has caused delamination of the concrete, especially near surfaces. The opening of the concrete by frost action has accelerated the alkali-silica reaction. This deleterious chemical reaction has caused additional disaggregation of the frost-damaged concrete. The interior concrete shows slight indications of alkali-silica reaction, but has not caused any significant damage to the interior concrete.

58. Another mechanism could have initiated cracking in selected piers in order for action to begin. For instance, vibration of the dam could have caused microcracking to occur at specific locations along the dam, i.e., on piers No. 5, No. 9, and No. 16. Frost action then could have started at these specific locations. The columns on these three

piers contain much more damaged concrete than do the other columns on any other piers. With all columns exposed to the same environment, and assuming that all the concrete in the columns was of the same quality, some unknown mechanism probably contributed to the damaged concrete that exists in piers No. 5, No. 9, and No. 16.

Structural Cracking

59. District personnel visited the dam and found a burst pipe on pier No. 16. They believe that the structural cracks in the columns on piers No. 9 and No. 16 were caused by bursting pipes and freezing water associated and adjacent to the pipe. Some WES personnel agree that the bursting pipe could cause the concrete to split as was found. However, it should not be overlooked that some of the structural cracks observed at the dam could have been caused in part or in whole by some loading condition other than freezing water. See Appendix D for photographs of the damage concrete due to the burst pipe.

60. The broken section of column No. 3 on pier No. 16 was removed and a 1-1/2-in. diameter pipe, a section of electrical conduit (ref drawing ML 24 56/1), was found to be split as if it had burst. The top of the conduit was once flush with the top of the columns and capped, however, it is now rusted off; see Photograph 5 in Appendix D. Evidently, rain water collecting on the top of the columns had drained into the conduit, frozen, burst the pipe, and cracked portions of the column. The columns on pier No. 9 were examined and it is believed that a similar situation to the one that caused the cracks on pier No. 16 developed on pier No. 9.

61. Original drawings show that 1-1/2-in. diameter electrical conduits are present in all downstream columns. Additionally, the downstream column on the Missouri side of each pier contains a 1-1/2-in. diameter drum-heater conduit which makes a 90-deg bend below the column and continues to a cast-iron junction box located above the trunnion shaft. A single 1/2-in. diameter conduit was provided for drainage of this entire line. According to lock personnel, the junction box and

drain line are silt laden. Also, short conduit elbows, plugged at both ends, were installed in the upstream and downstream cross walls which span between tops of the columns. The electrical conduits, the drum-heater conduits, drain conduits, and conduit elbows are potential sources of water which could be responsible for some of the deterioration of columns and the zone below and downstream of the trunnion shaft. Since these conduits are no longer in use, and if they are not proposed to be used in the future, it is recommended that they be cleaned out, grouted, and capped.

Removal and Repair of Damaged Concrete

62. The basic phenomena which initiated cracking in the concrete columns and piers were not identified in this study; therefore, it is impossible to suggest a repair procedure with any assurance that the same phenomena will not cause similar problems in the repair. It is most important that the basic cause of the cracking be ascertained before final selection of any repair procedure aimed at eliminating future cracking. Lacking this information, any repairs at present must be considered as only remedial work to improve the current condition of the columns and piers.

63. The surface cracks on the piers should be adequately sealed to keep water from infiltrating the concrete, especially in the area of the trunnion shaft. If the water is kept out, rusting of anchorage steel, frost action, and alkali-silica reaction will be greatly reduced.

64. There appear to be two basic approaches for repair of the concrete pier columns. The first approach should be considered an interim repair aimed at reducing the current rate of deterioration. The second approach would involve major rehabilitation of the pier columns.

65. The orientation and extent of cracking in the columns is such that the ingress of moisture (rain, snow, ice, etc.) from the top surfaces of the columns and cross members contributes to freezing and thawing and alkali-silica reaction within the concrete. Potential procedures to minimize this ingress of moisture would include (1) sloping the tops

of the columns and cross members to insure drainage towards the interior opening between the columns, (2) drilling holes along the lift joint between the columns and column facing to allow drainage to the outside of the columns, and (3) sealing the top surfaces of the columns and cross members. In this case the latter approach appears to offer ease of construction and the greatest potential for success. A number of materials are available to seal these horizontal surfaces; however, based on previous experience a heavy duty membrane of rubberized asphalt integrally bonded to polypropylene mesh is suggested. The use of such a membrane should be restricted to horizontal surfaces with the possible exception of those vertical surfaces within 3 to 6 in. of the tops of the columns. Such an overlap would allow installation of a mechanical band around the columns to further secure the membrane. Specifications for this membrane are included in Table 3. This approach should reduce the rate of deterioration while additional work is being done to determine the basic cause of deterioration or until major rehabilitation of the pier columns is initiated.

66. Major rehabilitation would involve removal of unsound concrete from those areas previously described as moderately or severely deteriorated and replacement with new concrete; i.e., the upper part of the downstream face of the piers and certain pier columns. It is anticipated that the location and extent of reinforcing steel and the strength of the existing concrete will be such that concrete removal may be difficult. The concrete removal operation should be closely monitored to insure that the amount of concrete removed is kept to the minimum necessary for replacement with new concrete. In general this minimum depth would be that necessary to completely expose the outer layer of reinforcing.

67. It is recommended that the surface removal of distressed/deteriorated concrete from the piers and the bridge columns be done using high-pressure water jets. The reasoning behind the selection of the water jet over conventional removal methods is amount of reinforcing steel in the concrete. The water jet leaves the steel reinforcing clean and undamaged for reuse, thus eliminating the need for replacement steel. In addition to reinforcing the concrete, the steel will act as a dowel

between the existing and replacement concrete allowing loads to be transferred between them. Other advantages of the water jet are:

a. Minimal damage to the concrete that remains is produced.

b. Irregular shaped volumes can be removed.

c. No dust and little noise are produced.

The main concern with the water jet is its variable productivity rate. Under certain conditions, such as cutting concrete containing large abrasive-resistant aggregate, this rate can be very low. To avoid contracting a jet with undesirable productivity rate, it is recommended that a short-term (say, 3 days) pilot test program be used to determine the productivity and acceptability of the jet. The following contractors are among the most promising for doing a satisfactory removal job:

Flow Industries
Kent, Washington
(206) 872-8500

McCartney Mfg Co., Inc.
Baxter Springs, Kansas
(316) 856-2151

iiT Research Institute
Chicago, Illinois
(312) 567-4400

Daedalean Associates, Inc.
Woodbine, Maryland
(301) 442-2620

68. In those cases where 50 percent or more of the concrete column area is expected to require removal, consideration should be given to providing temporary support for the column loads and completely removing and replacing the existing columns. Either sawing or explosives is suggested for concrete removal in these instances.

69. Replacement concrete should be proportioned in accordance with current standard practice. Particular attention should be given to freezing and thawing resistance and the potential for alkali-silica reaction.

70. Some recent rehabilitation projects have encountered cracking in the replacement concrete. In general these problems were associated with concrete overlays which were rather thin relative to the remaining

concrete monoliths. Such problems appear to be the result of the tremendous restraint provided by the existing concrete making thermal considerations during construction even more important than in new construction. While the concrete sections involved in this work are relatively small, the potential for thermal cracking still exists. Attention should be given to minimize temperature differentials between existing and replacement concrete during placing and curing of the replacement concrete. Also, differentials in temperature between the replacement concrete and ambient at the time of form removal and immediately following should be within 25 F or less.

71. Depending upon when this repair is scheduled, a vacuum polymer impregnation technique currently under development may have potential application. This technique consists of wrapping the structure in polyethylene and creating a vacuum through the use of a vacuum pump. A resin is then injected and flows, through the cracks in the structure, towards the source of the vacuum. The vacuum evacuates water and fine contaminants from the fissures prior to impregnation with the resin. With the aid of the vacuum, resin penetrates throughout the crack system and dust or loose particles acts as a filler in the resin. Repair is accomplished without removal of damaged concrete. Fine aggregate may be mixed with the resin to repair large cracks, voids, or badly deteriorated surfaces. The technique is currently being investigated by application to damaged 6-in. by 12-in. cylinders and 3-1/2- by 4-1/2- by 16-in. beams. Damage is being produced for laboratory testing by compressive and splitting tensile testing, exposure to high temperature (1000^{o} F), accelerated freezing and thawing, and accelerated alkali-silica reaction. If laboratory testing continues to show favorable results, this technique may warrant field testing on one or more of the damaged piers or columns.

REFERENCES

1. U. S. Army Engineer Waterways Experiment Station Petrographic Report, dated 23 January 1976, subject, "Tests and Examination of Concrete Cores from Lock and Dam 24 and Lock and Dam 25," Vicksburg, Miss.

2. U. S. Army Engineer Waterways Experiment Station Petrographic Report, dated 4 December 1978, subject, "Project Examination of Fragmented Concrete Cores from Lock and Dam 24, U. S. Army Engineer District, St. Louis," Vicksburg, Miss.

3. Thornton, Henry T., Jr. and Glass, Dale, "Ultrasonic Velocity Measurements in Concrete, Lock and Dam No. 24, Mississippi River," WES Miscellaneous Paper SL-80-2, Apr 1980, Vicksburg, Miss.

4. ACI Committee 201, "Guide for Making a Condition Survey of Concrete in Service," ACI Journal, Proceedings, Vol 65, No. 11, Nov 1968, pp 905-918.

5. U. S. Army Engineer District, St. Louis, "Periodic Inspection Report No. 3, Lock and Dam No. 24, Mississippi River," Sep 1977.

6. U. S. Army Engineer Waterways Experiment Station, CE, "Handbook for Concrete and Cement," with quarterly supplements, Vicksburg, Miss., Aug 1949.

Table 1

Inspection Team, Lock and Dam No. 24

Name	Organization
Riley Pope	SLD-ED
Mel Stegall	SLD-ED
Don Buckley	Lockmaster
Carl Pace	WESSC
Henry Thornton	WESSC
Richard Stowe	WESSC

Table 2

Directions, Locations, Elevations, Horizontal Boring Depths, and Starting Dates

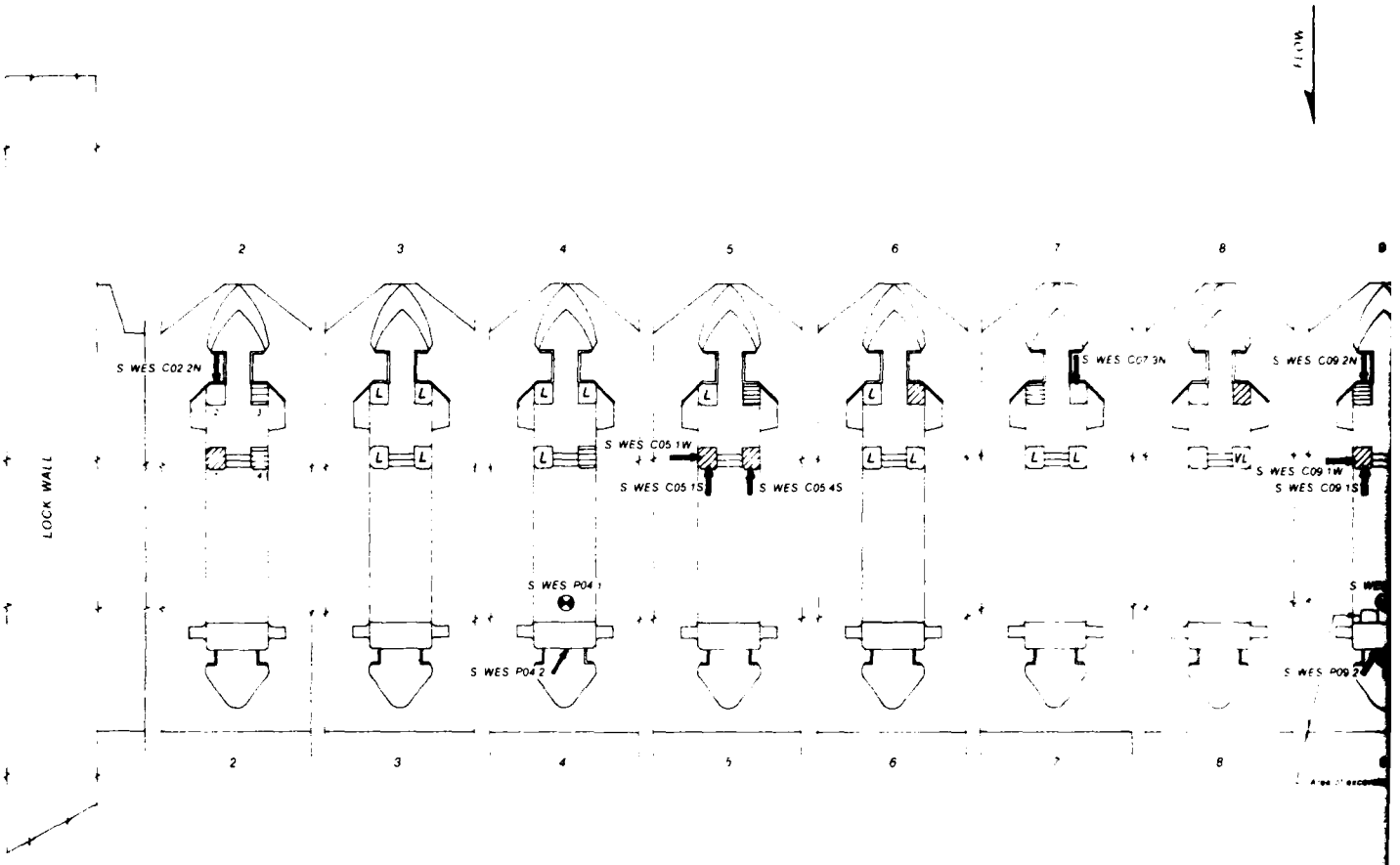
Boring No. S WES	Direction of Boring	Location	El Top of Boring ft	El Bottom of Boring ft	Depth of Horizontal Boring, ft	Start Date
P04.1-80	Vertical	Pier, D/S portion	454.0	440.3		30 Oct 1980
P04.2-80	Inclined 90°	Pier, D/S portion	448.0	448.0	6.4	28 Nov 1980
P09.1-80	Vertical	Pier, D/S portion	454.0	439.8		28 Oct 1980
P09.3-80	Vertical	Pier, D/S portion	444.0	431.2		24 Nov 1980
P09.2-80	Inclined 90°	Pier, D/S portion	448.0	448.0	5.9	06 Nov 1980
P15.1-80	Vertical	Pier, D/S portion	454.0	412.9		21 Oct 1980
P15.2-80	Inclined 90°	Pier, D/S portion	448.1	448.1	6.55	07 Nov 1980
C02.2N-80	Inclined 90°	Column	468.6	468.6	3.5	21 Nov 1980
C07.3N-80	Inclined 90°	Column	464.7	464.7	3.5	13 Nov 1980
C13.2N-80	Inclined 90°	Column	462.0	462.0	3.5	11 Nov 1980
C13.3N-80	Inclined 90°	Column	460.0	460.0	3.55	21 Nov 1980
C09.2N-80	Inclined 90°	Column	469.2	469.2	3.6	12 Nov 1980
C09.3N-80	Inclined 90°	Column	467.3	467.3	3.5	19 Nov 1980
C16.3N-80	Inclined 90°	Column	475.4	475.4	3.5	10 Nov 1980
C16.3E-80	Inclined 90°	Column	469.0	469.0	3.0	20 Nov 1980
C05.1W-80	Inclined 90°	Column	466.5	466.5	3.1	18 Nov 1980
C05.1S-80	Inclined 90°	Column	465.5	465.5	3.5	17 Nov 1980
C05.4S-80	Inclined 90°	Column	466.5	466.5	3.5	18 Nov 1980
C09.1W-80	Inclined 90°	Column	466.0	466.0	3.05	14 Nov 1980
C09.1S-80	Inclined 90°	Column	468.0	468.0	3.50	14 Nov 1980
C09.4S-80	Inclined 90°	Column	465.7	465.7	3.5	19 Nov 1980
C16.1S-80	Inclined 90°	Column	475.45	475.45	3.6	08 Nov 1980
C16.1W-80	Inclined 90°	Column	466.9	466.9	3.1	13 Nov 1980
C16.2N-80	Inclined 90°	Column	467.45	467.45	3.5	10 Nov 1980
H5.1-80	Inclined 90°	Column	471.6	471.6	0.72	01 Dec 1980

Table 3

Description of Asphaltic Membrane

TYPE AND CONSTRUCTION	SPECIFICATIONS			APPLICATIONS
	PROPERTY	AVERAGE TEST VALUE	TEST METHOD	WATERPROOFING
STANDARD GRADE Polyethylene Sheet 0 1mm Bitumen-Rubber Compound 1 5mm Total 1 6mm Interwound Release Paper 0 2mm	PERMEANCE SI (Ng m² Sec Pa) Polyethylene Rubberized Bitumen	 5 72 1 43	 ASTM E 96 METHOD B	Above & Below Ground foundations tanking plazas and terraces non-exposed roofing and reservoirs
	WATER ABSORBTION % by weight in 72 hours	0 22%	ASTM D 1228	
	PLIABILITY 180° bend over 25mm mandrel at -32 C	Unaffected	ASTM D 146	
	CYCLING over crack at -26°C	Unaffected	100 cycles over 0·6 4mm distance	
	25mm joint at -26°C	Unaffected	1000 cycles over 19 0·31 8mm distance	
	TENSILE STRENGTH Polyethylene	280 kg sq cm 27 580 kPa	ASTM D 412 (Die C) modified	
	ELONGATION % of original distance at ultimate failure *Rubberized-Bitumen*	300%	ASTM D 412 (Die C) modified	
	PUNCTURE RESISTANCE Stretched by Blunt Object	25kg	ASTM E 154	
	PEEL ADHESION Membrane is peeled at 90% angle	1 86kg cm width	7 days dry @ 21 C 7 days dry @ 49 C 7 days wet @ 21 C	
HEAVY DUTY Polypropylene Mesh 0 3mm Bitumen-Rubber Compound 1 5mm Total 1 8mm Interwound Release Paper 0 2mm	Specifications as for STANDARD GRADE except for the following PUNCTURE RESISTANCE Stretched by blunt Object	118kg	ASTM E 154	Vehicular traffic structures parking decks bridge decks and highways
BITUTHENE CRM* Polyethylene Sheet 0 2mm Bitumen-Rubber Compound 1 5mm Total 1 7mm Interwound Release Paper 0 2mm	Specifications as for STANDARD GRADE except PLIABILITY 180° bend over 6 4mm mandrel at -37	Unaffected	ASTM D 146	New Roofing Re-Roofing Remedial Roofing
	CYCLING over crack at -32 C	Unaffected	200 cycles over 0·6 4mm	
	6 4mm joint at -32°C	Unaffected	3 000 cycles over 3 2·9 5mm distance	
	PUNCTURE RESISTANCE Stretched by blunt object	120kg	ASTM E 154	

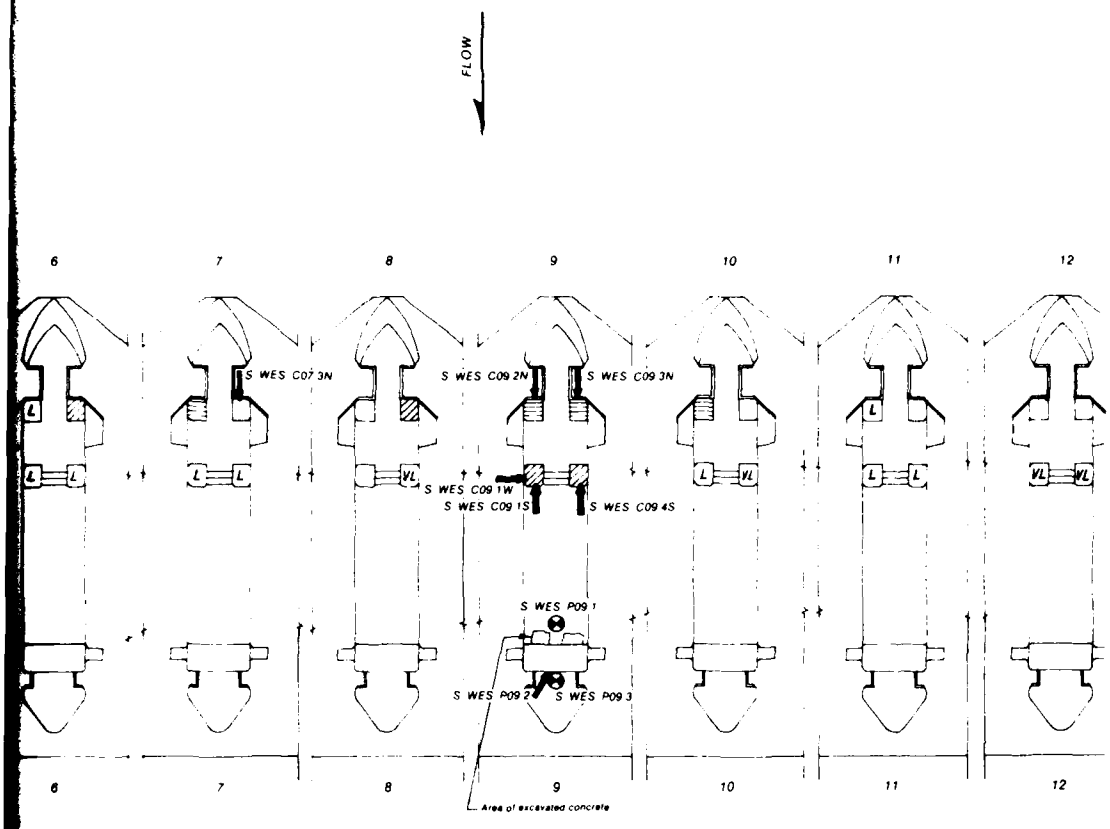
CRM = Compliant roofing membrane



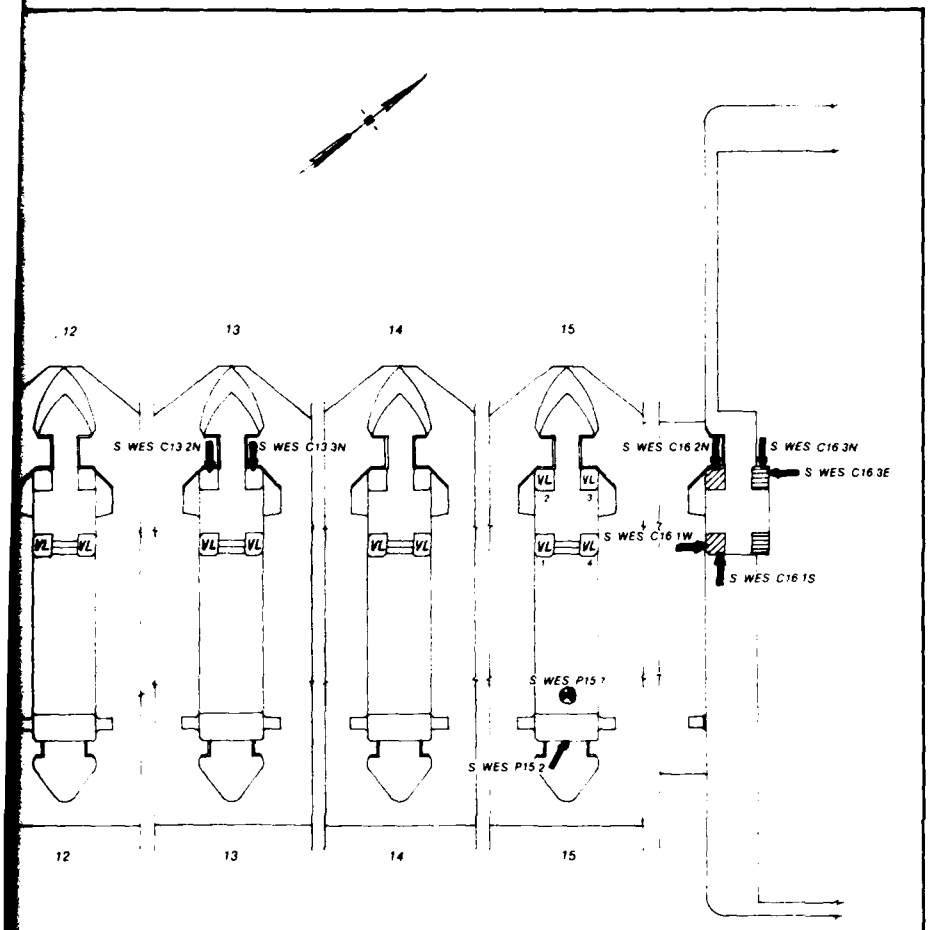
PLAN VIE

SYMBOL	CONCRETE CONDITION	DESCRIPTION	No. of COLUMNS	PERCENT TOTAL
	OK	No signs of deterioration	12	20
VL	Very light deterioration	Local hairline, one per 9 ft² area, slight exudation	12	20
L	Light deterioration	Local cracks, fine * one per 9 ft² area, slight exudation	17	28
	Moderate deterioration	Zone cracking, medium * one crack per 3 to 4 in, heavy exudation covering 50% of zone	10	17
	Severe deterioration	Zone cracking, medium to wide * one crack per 2 to 3 in, heavy exudation covering 75% of zone	9	15
*		Fine 1 mm (0.04 in.) Medium 1 to 2 mm (0.04 to 0.08 in.) Wide 2 mm (0.08 in.)		
		Vertical boring, 8 × 8-1/2 in. (5.7 in. core)		
		Horizontal boring, in pier, 8 × 8-1/2 in. (5.7 in. core)		
		Vertical and horizontal arrows denote horizontal borings in columns, 6 × 8-1/2 in. (5.7 in. core)		

NOTE: A small area of severly deteriorated concrete exist downstream of the trunnion shaft, the zone is not shown on this plate, see Photo No. 1, Appendix A, for typical damage zone



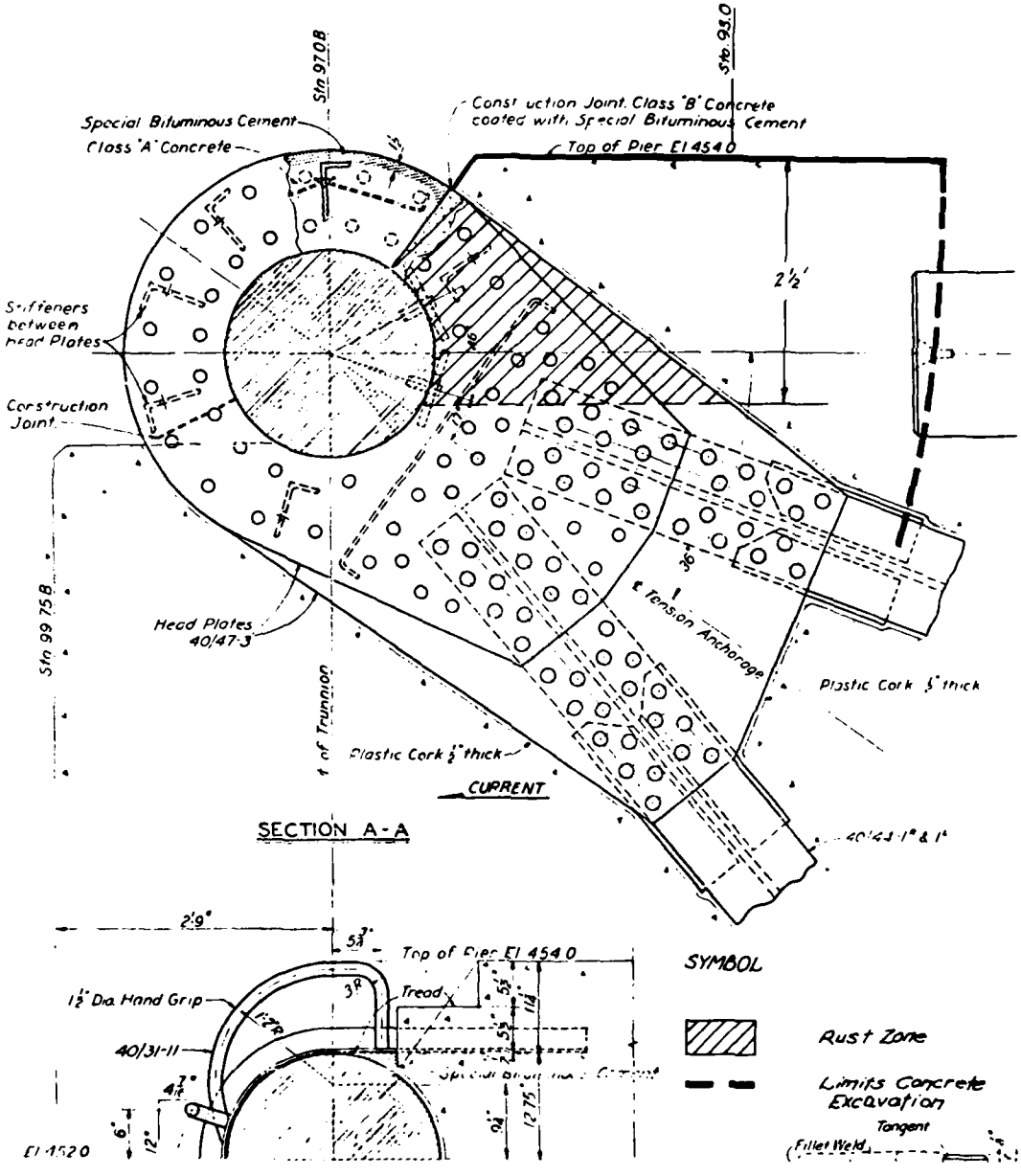
PLAN VIEW DAM



CONDITION SURVEY
LOCK AND DAM #24
CONDITION OF CONCRETE COLUMNS
April 1991

PLATE 1

3



Detail showing rusted zone on anchorage collar and approximate extent of excavated concrete. Reference M-124 40/45.1

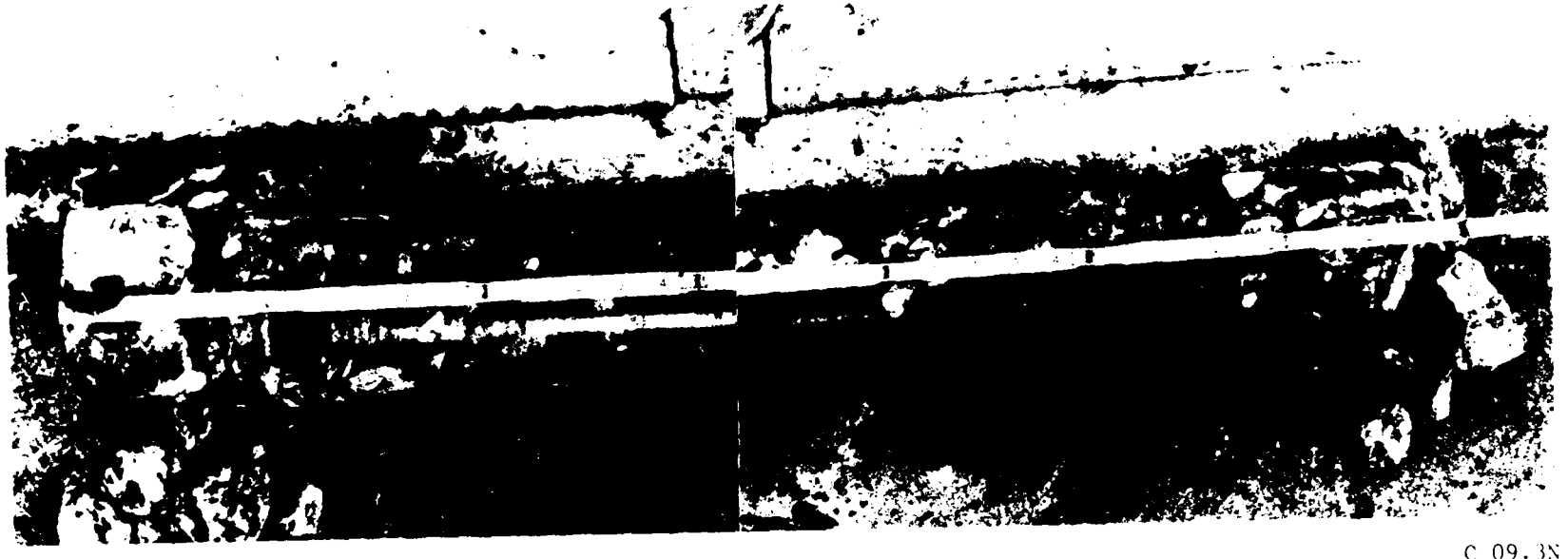
PLATE 2

PLATE 3

PLATE 4

MODERATE

PLATE 5



MODERATE

C 09.3N

PLATE 9

C 16.2N

C 16.1S

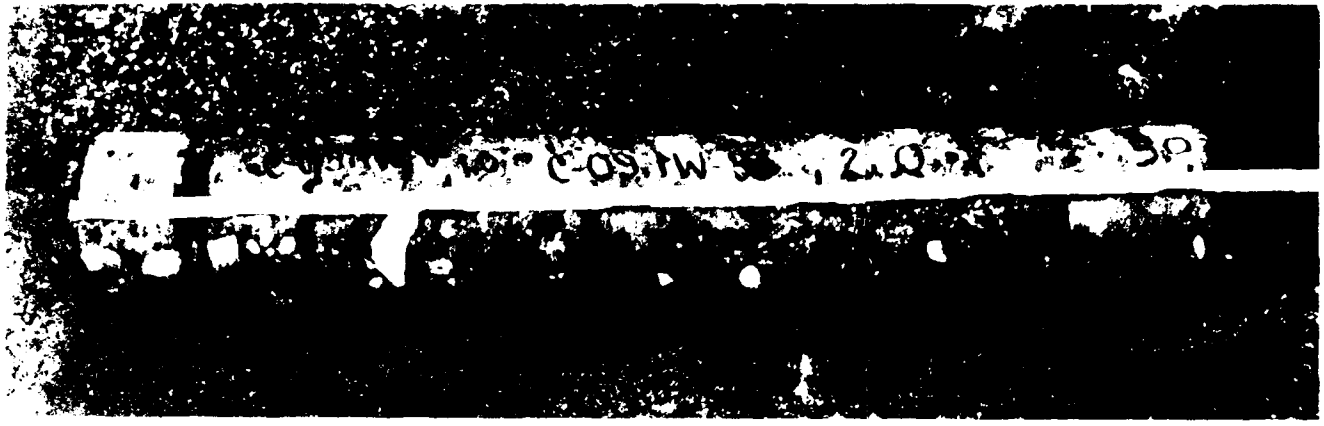
SEVERE

PLATE 7

SEVERE

PLATE 8

PLATE 9



C 09.1W

SEVERE

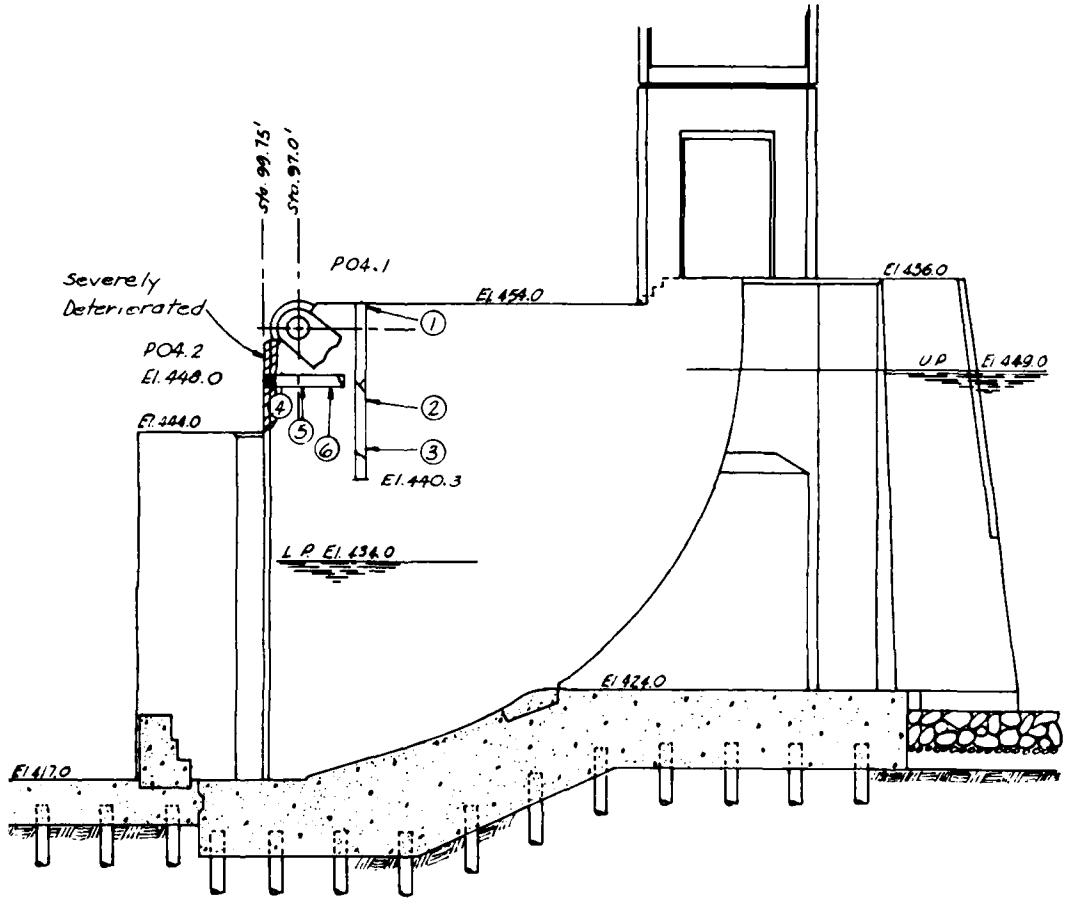
C 09.1S

PLATE 10

P 09.2
PIER

PLATE 11

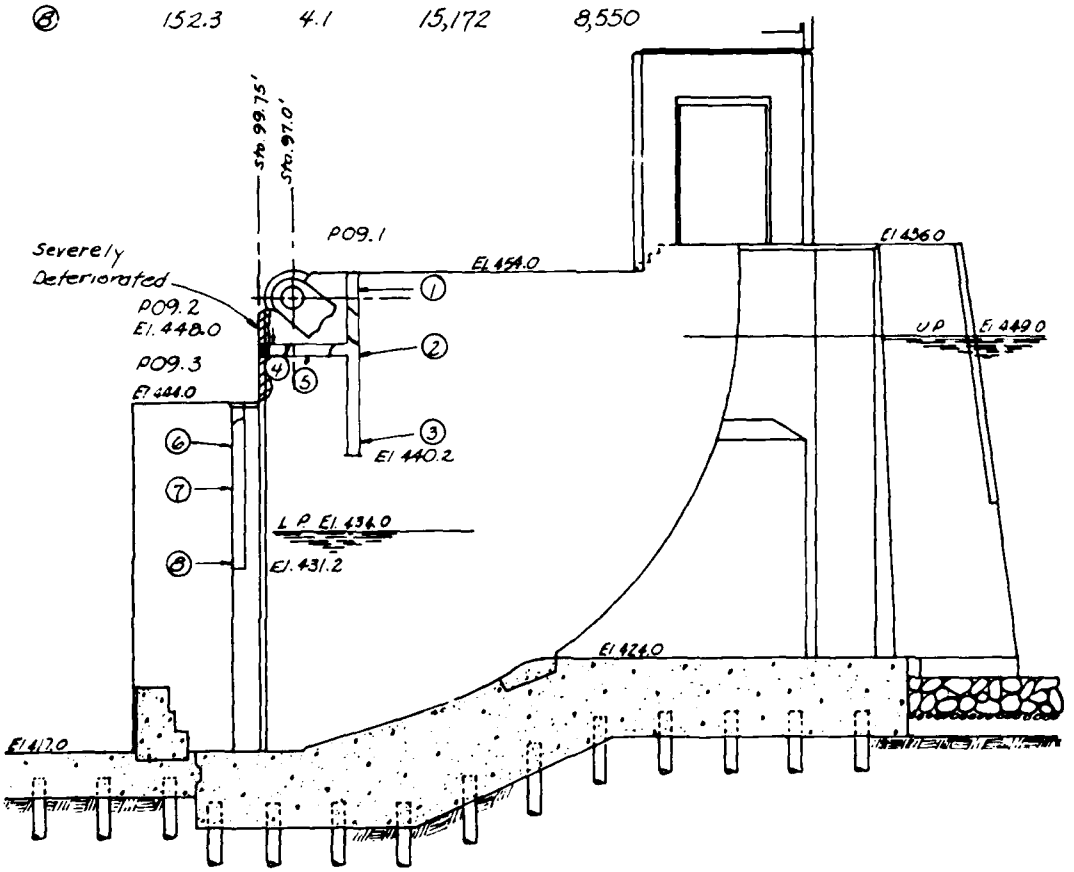
	γ lb/ft^3	w pcf	V_p fps	q_u psi	E $\times 10^6$ psi	ν
①	155.4	5.0	15,651	8,050		
②	153.5	4.7	15,873	10,410		
③	152.3	4.6	14,166	10,020	5.53	0.17
④	154.0	4.6	14,416	7,180	1.99	0.12
⑤	151.4	3.9	16,527	7,800		
⑥	152.4	4.6	16,639	6,970	6.03	0.18



CROSS SECTION PIER #4

PLATE 12

	γ lb/ft^3	ω pct	Vp fps	q_u psi	E $\times 10^6$ psi	ν
①	152.3	4.5	13,715	6,830	2.98	0.13
②	152.3	4.7	15,037	7,910		
③	151.6	5.0	15,064	9,130	5.20	0.18
④	152.1	5.6	13,515	7,970	2.89	0.21
⑤	148.6	4.0	15,625	8,300	4.95	0.18
⑥	151.0	4.5	14,987	7,960		
⑦	154.3	5.2	15,024	9,010	5.34	0.18
⑧	152.3	4.1	15,172	8,550		



CROSS SECTION PIER #9

PLATE 13a

PIER NO. 9

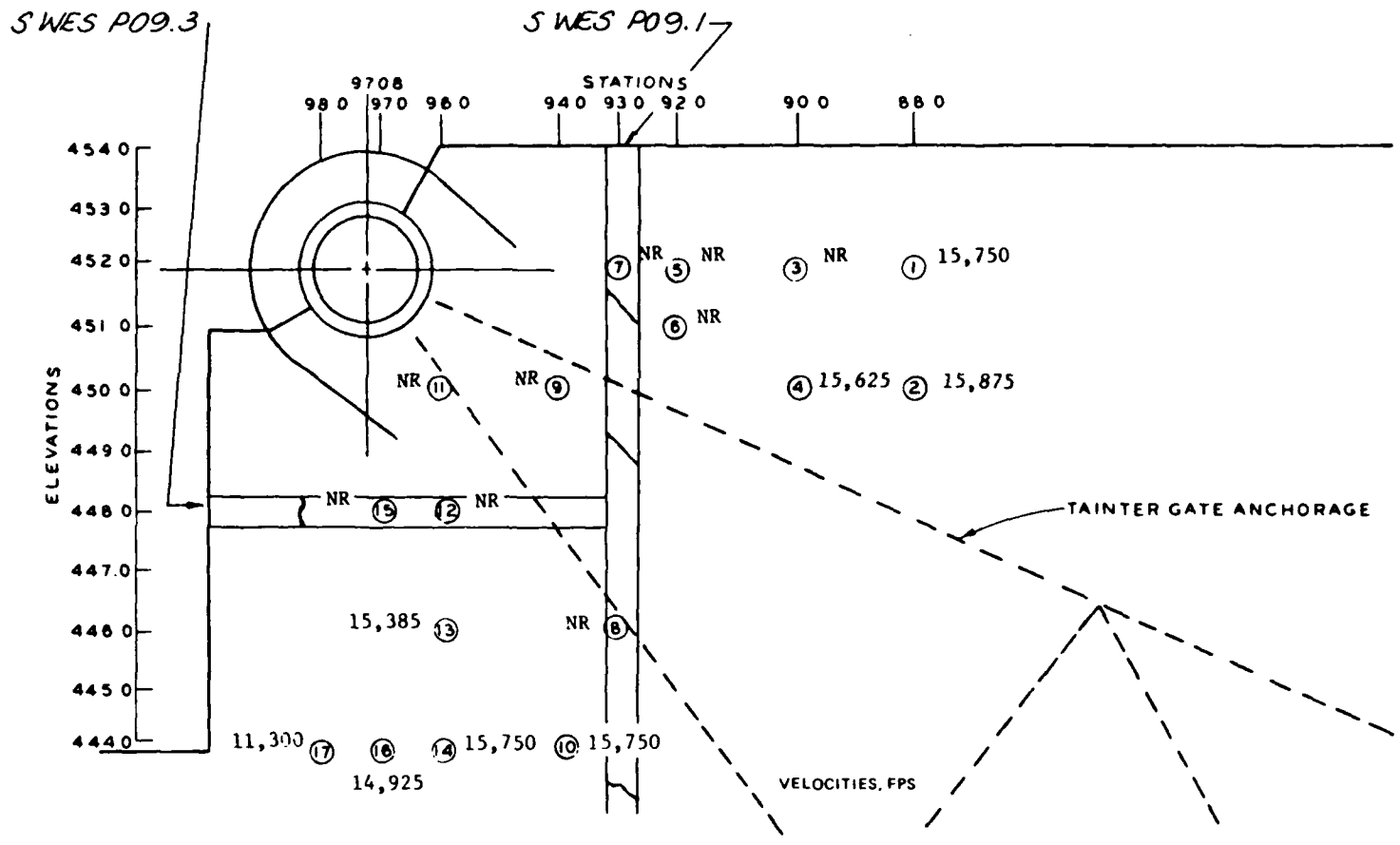
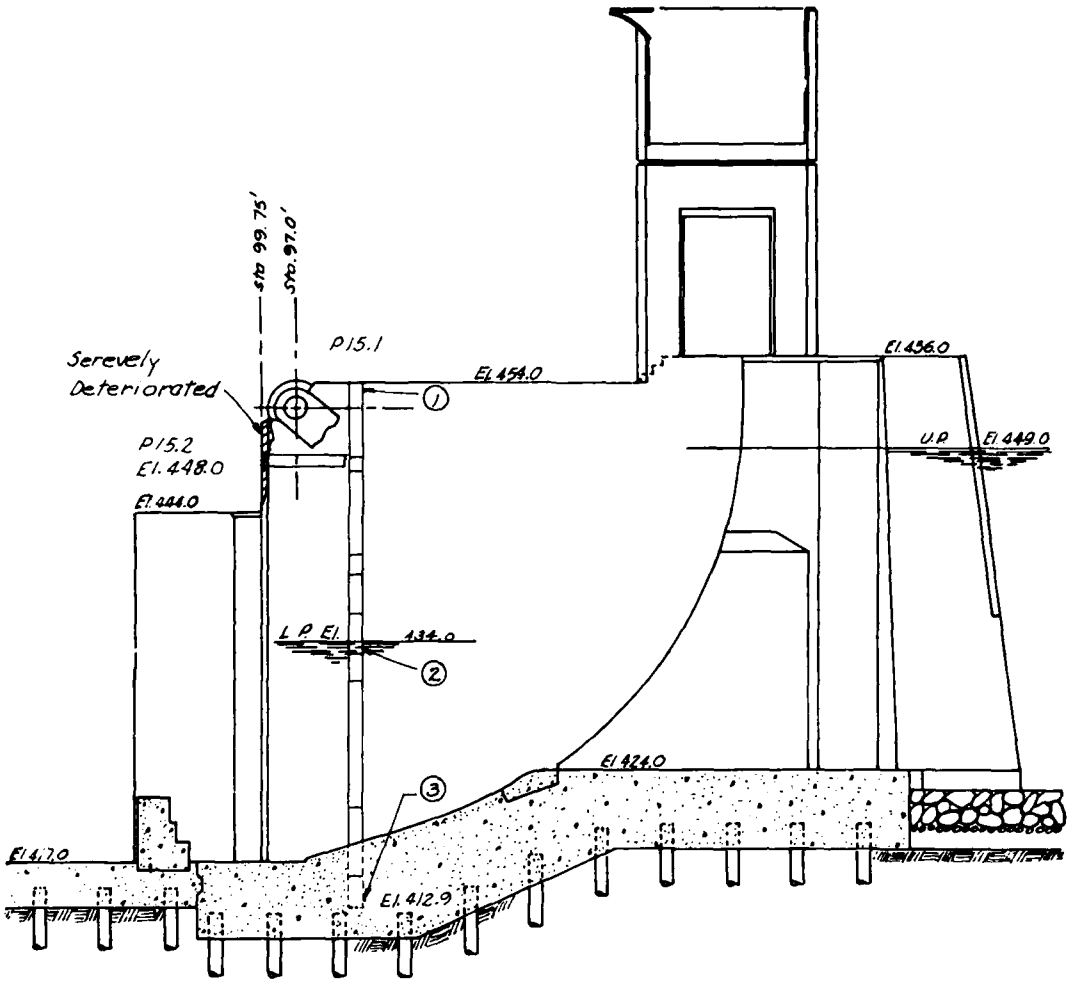


PLATE 13b

	γ lb/ft^3	ω pct	V_p fps	q_u psi	E $\times 10^6$ psi	ν
①	151.0	6.0	14,404	5,840	2.80	0.14
②	151.6	4.2	15,126	8,380	5.84	0.22
③	151.0	4.3	15,625	7,000		



CROSS SECTION PIER #15

PLATE 14

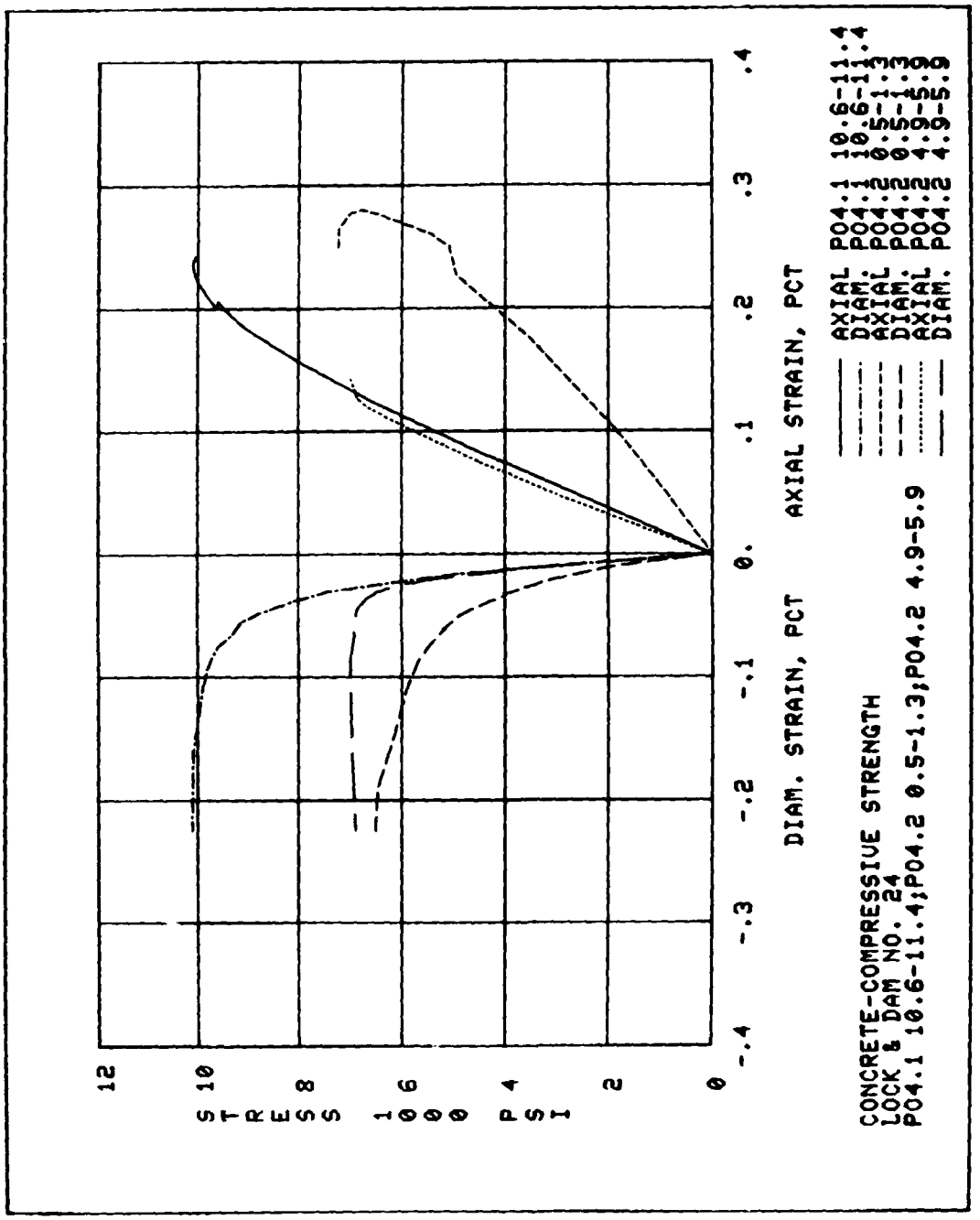

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
P04.1 10.6-11.4;P04.2 0.5-1.3;P04.2 4.9-5.9
AXIAL P04.1 10.6-11.4
DIAM. P04.1 10.6-11.4
AXIAL P04.2 0.5-1.3
DIAM. P04.2 0.5-1.3
AXIAL P04.2 4.9-5.9
DIAM. P04.2 4.9-5.9
DIAM. STRAIN, PCT
AXIAL STRAIN, PCT
STRESS 1000 PSI
12
10
8
6
4
2
0
-.4
-.3
-.2
-.1
0.
.1
.2
.3
.4

PLATE 15

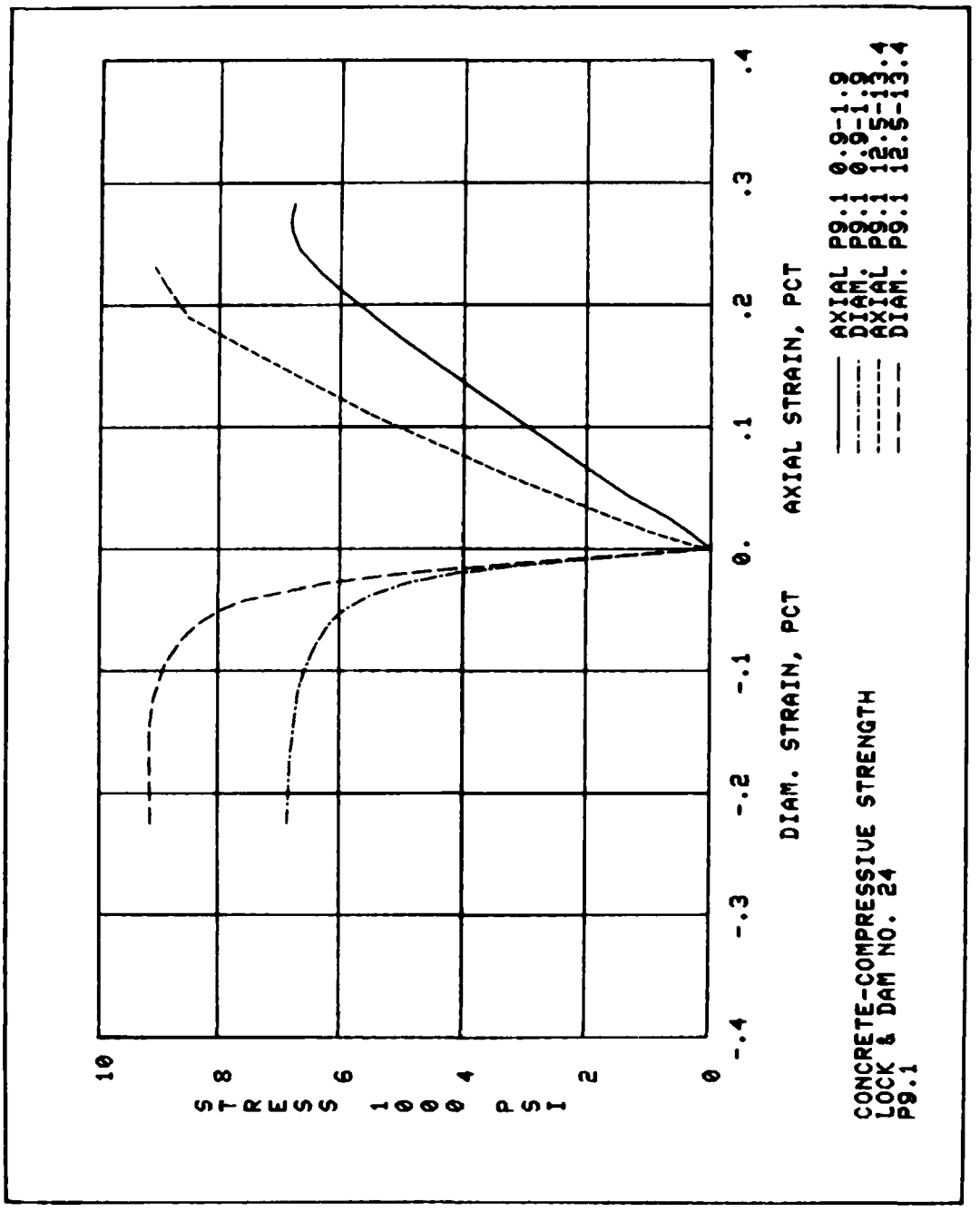
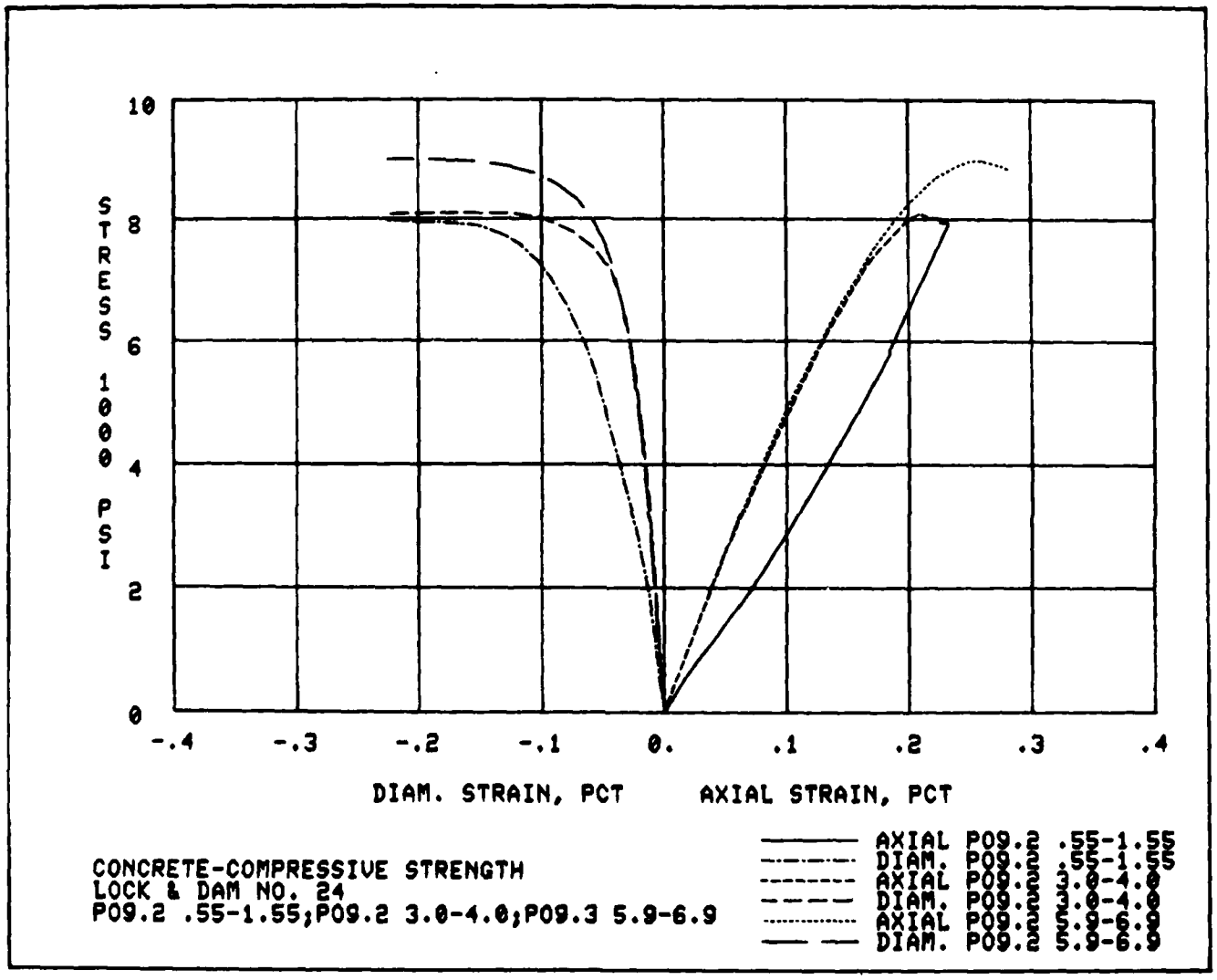

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
P9.1
STRESS 1000 PSI
10
8
6
4
2
0
-.4
-.3
-.2
-.1
0.
.1
.2
.3
.4
DIAM. STRAIN, PCT
AXIAL STRAIN, PCT
AXIAL P9.1 0.9-1.9
DIAM. P9.1 0.9-1.9
AXIAL P9.1 12.5-13.4
DIAM. P9.1 12.5-13.4

PLATE 16



CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
P09.2 .55-1.55;P09.2 3.0-4.0;P09.3 5.9-6.9

PLATE 17

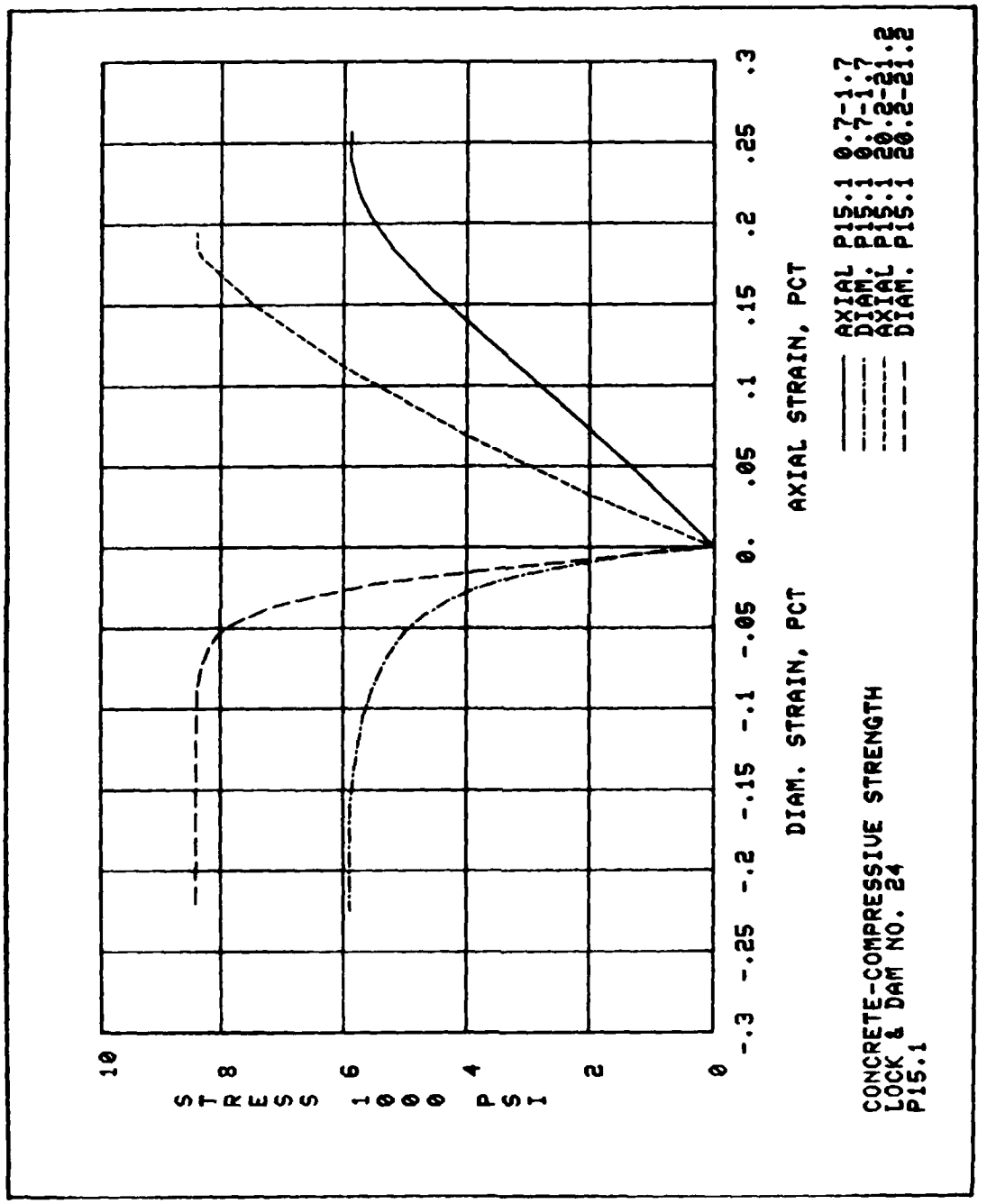
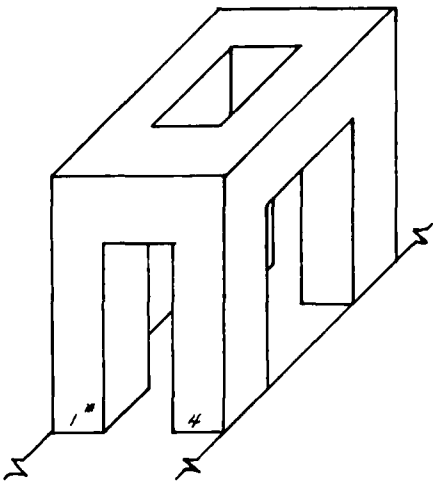
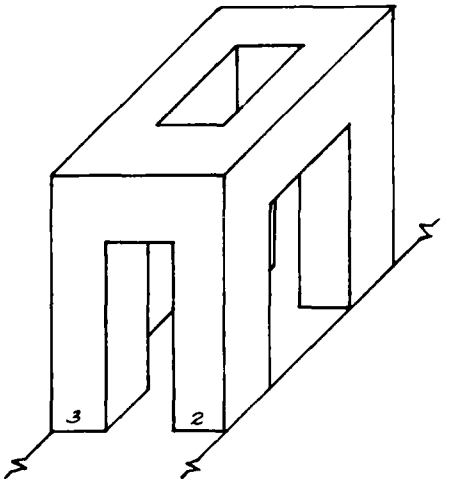

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
P15.1
DIAM. STRAIN, PCT
AXIAL STRAIN, PCT
STRESS 1000 PSI
AXIAL P15.1 0.7-1.7
DIAM. P15.1 0.7-1.7
AXIAL P15.1 20.2-21.2
DIAM. P15.1 20.2-21.2

PLATE 18

COLUMNS PIER #1



LOOKING UPSTREAM



LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

No damaged concrete, no core take

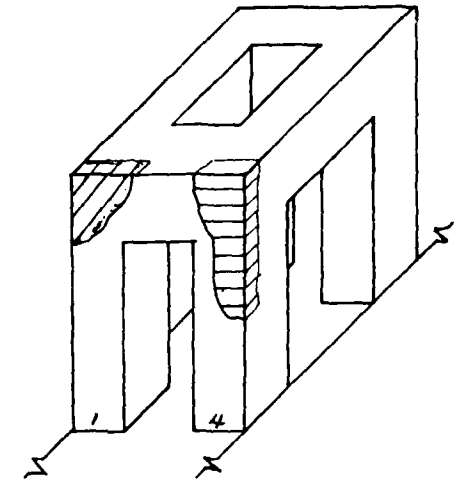
* Column numbers

OK MODERATE SEVERE

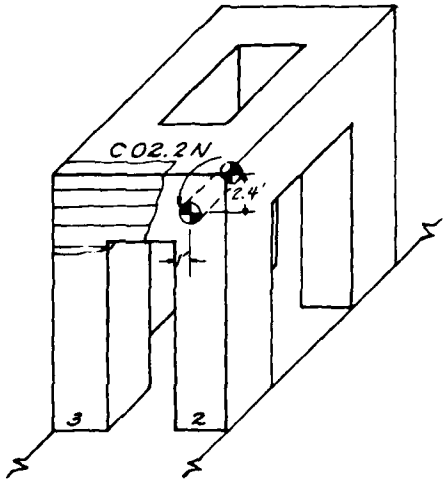
SCALE 1/8" = 1'

PLATE 19

COLUMNS PIER #2



LOOKING UPSTREAM



LOOKING DOWNSTREAM

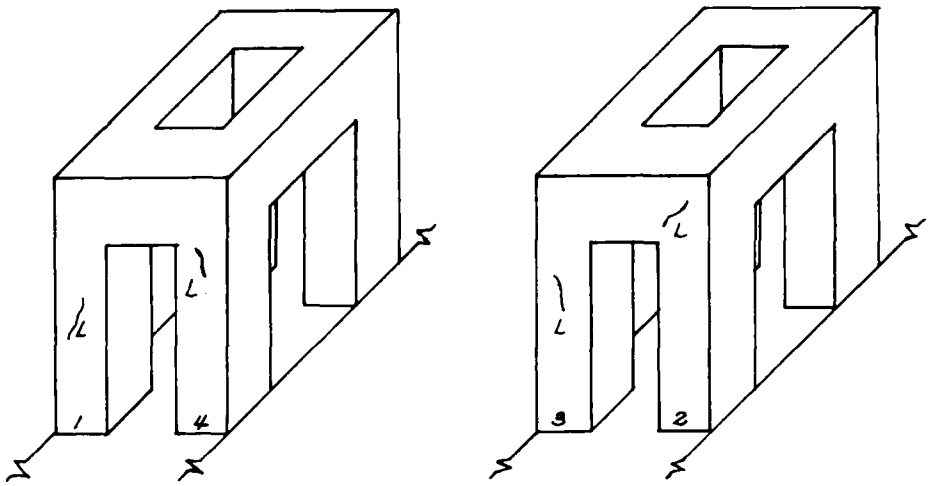
CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
OK	C02.2N	γ, lb/ft^3		152.9	
		W, pct		4.4	
		Vp, fps		16,196	
		q_u, psi		8,870	

OK MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 20

COLUMNS PIER #3



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

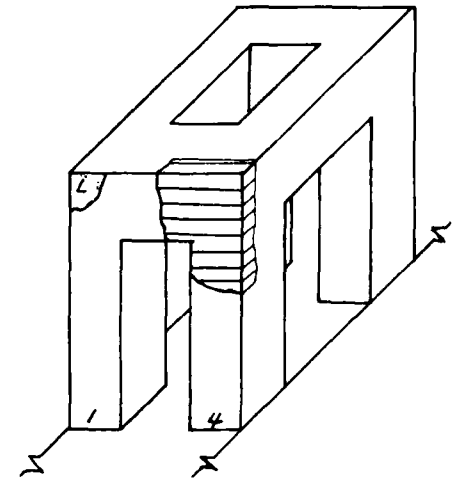
Lt damage over columns, no core taken.

L LIGHT MODERATE SEVERE

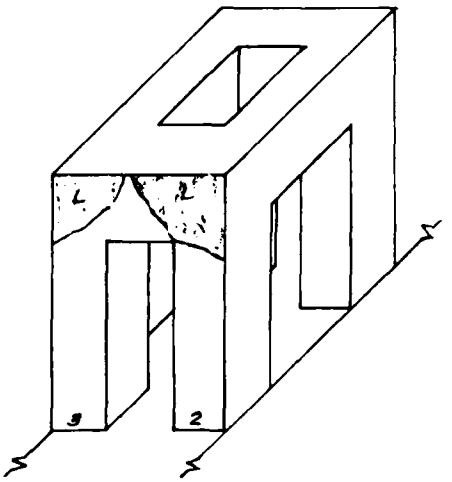
SCALE 1/8" = 1'

PLATE 21

COLUMNS PIER #4



LOOKING UPSTREAM



LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

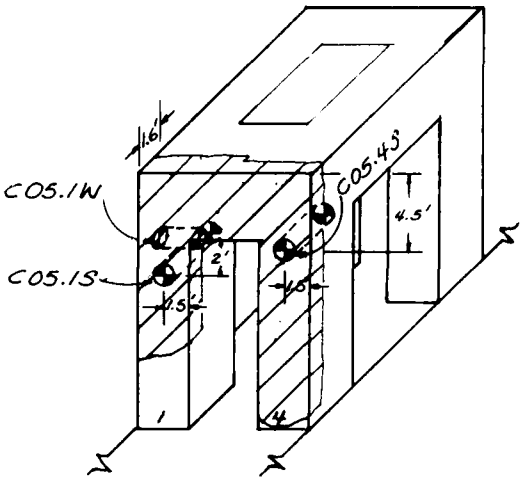
No core taken.

L LIGHT MODERATE SEVERE

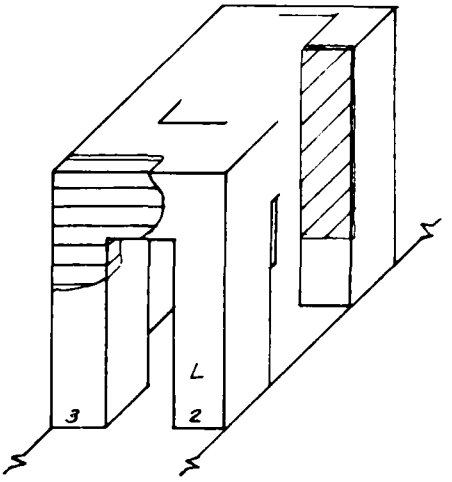
SCALE 1/8" = 1'

PLATE 22

COLUMNS PIER #5



LOOKING UPSTREAM



LOOKING DOWNSTREAM

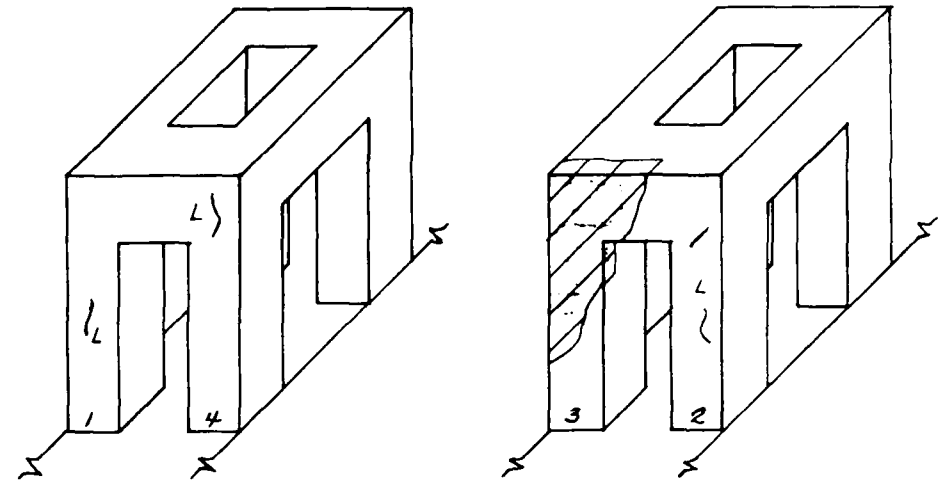
CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
SEV	C05.1S	γ, lb/ft^3	148.7	150.0	154.6
		w, pcf	5.6	5.1	5.0
		Vp, fps	4,602	14,303	9,093
		qu, psi	3,860	5,380	5,750
		E, x10^{6}psi	0.24	0.88	
SEV	C05.4S	γ, lb/ft^3			147.8
		w, pcf			5.4
		Vp, fps			10,707
		qu, psi			3,570
		E, x10^{6}psi			0.36
SEV	C05.1W	No tests			

L LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 23

COLUMNS PIER #6



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

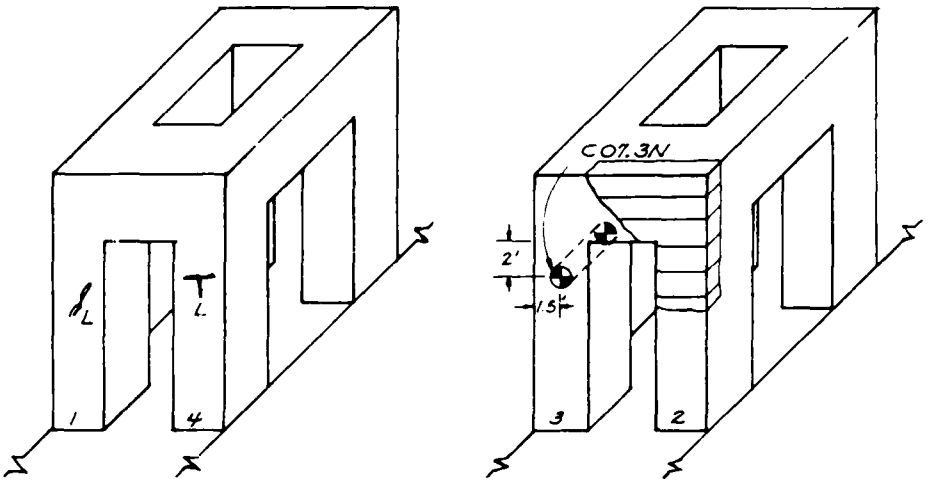
Lt. damage over columns 1, 2 & 4. No core taken.

L LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 24

COLUMNS PIER #7



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
OK	C07.3N	No tests			

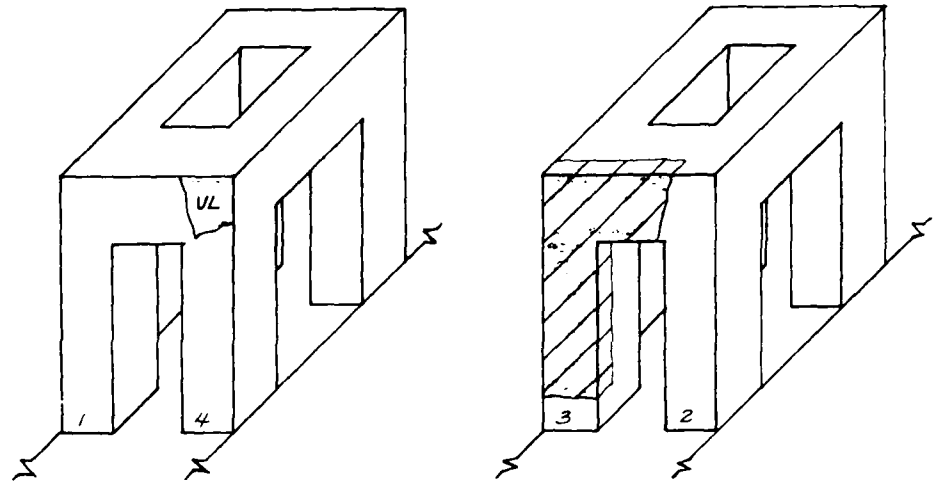
Lt. damage over columns 1 & 4

LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 25

COLUMNS PIER #8



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

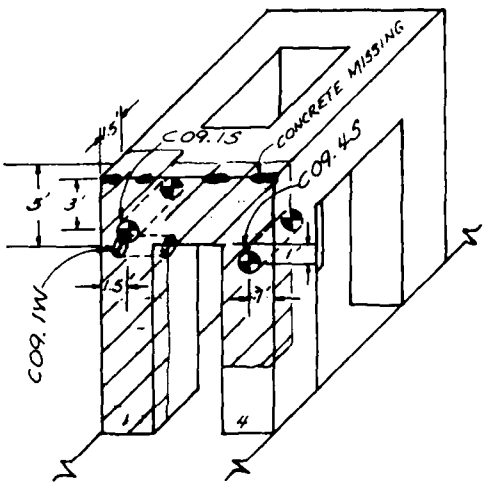
Very light damage over column 4

VL VERY LIGHT MODERATE SEVERE

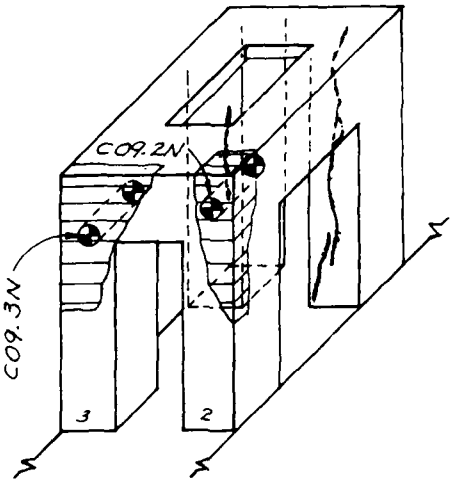
SCALE 1/8" = 1'

PLATE 26

COLUMNS PIER #9



LOOKING UPSTREAM



LOOKING DOWNSTREAM

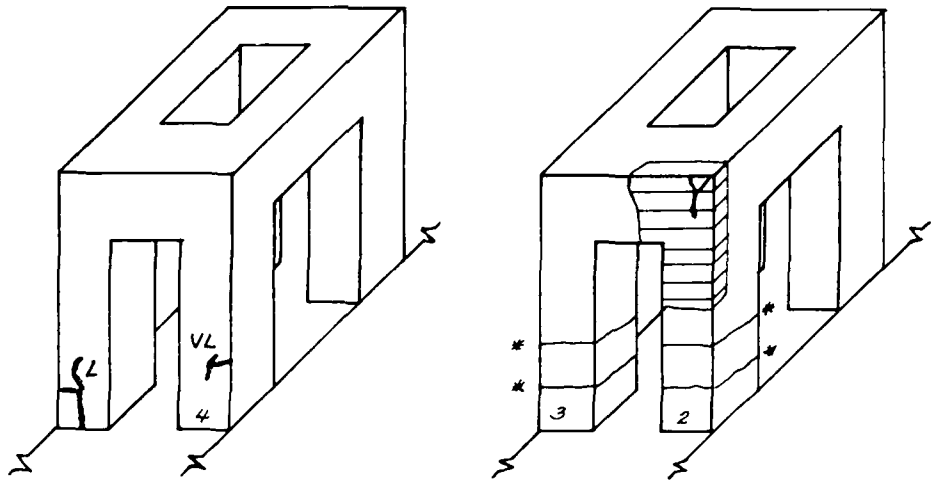
CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
3EV	C09.1S	γ, lb/ft^3	149.1	149.5	
		w, pct	6.0	6.4	
		Vp, fps	5,781	11,721	
		qu, psi	2,880	3,080	
		E, x 10^6 psi	0.18	0.63	
MOD	C09.3N	γ, lb/ft^3	160.8	150.8	
		w, pct	5.7	4.8	
		Vp, fps	11,050	12,725	
		qu, psi	6,680	7,040	
		E, x 10^6 psi	1.72	2.42	
		ν	0.17	0.14	
SEV	C09.4S	γ, lb/ft^3	150.1	146.5	
		w, pct	6.2	5.5	
		Vp, fps	8,924	10,709	
		qu, psi	2,070	4,280	
		E, x 10^6 psi	0.25	0.38	

STRUCTURAL CRACK MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 27

COLUMNS PIER #10



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

No core taken
Very light colum 4; light colum 1.

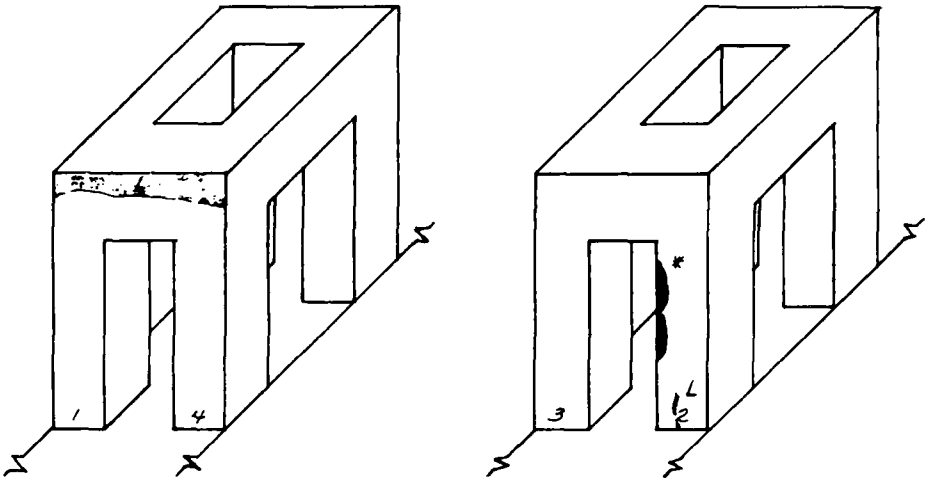
* CRACKS CAUSED BY BARGE IMPACT, EPOXY FILLED.

VL VERY LIGHT
L LIGHT
MODERATE
SEVERE

SCALE 1/8" = 1'

PLATE 28

COLUMNS PIER #11



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

No core taken.

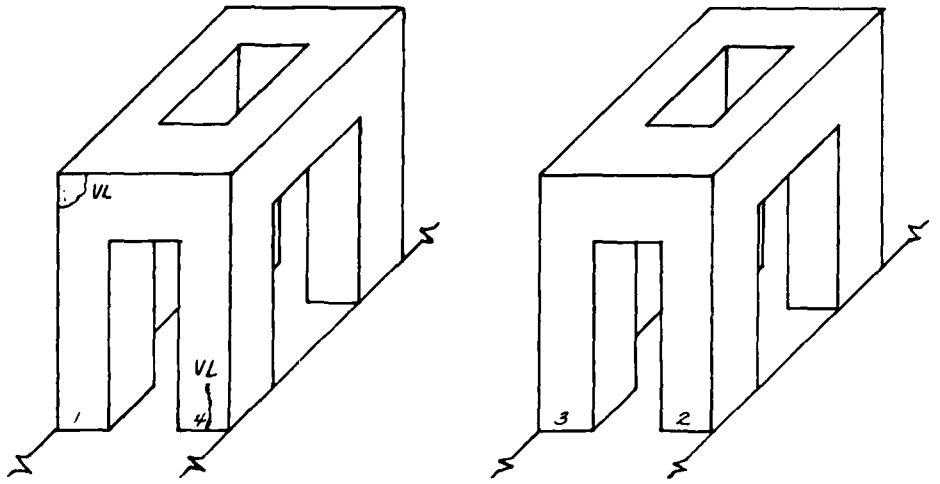
* Slight honeycombing, no exudation.

LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 29

COLUMNS PIER #12



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

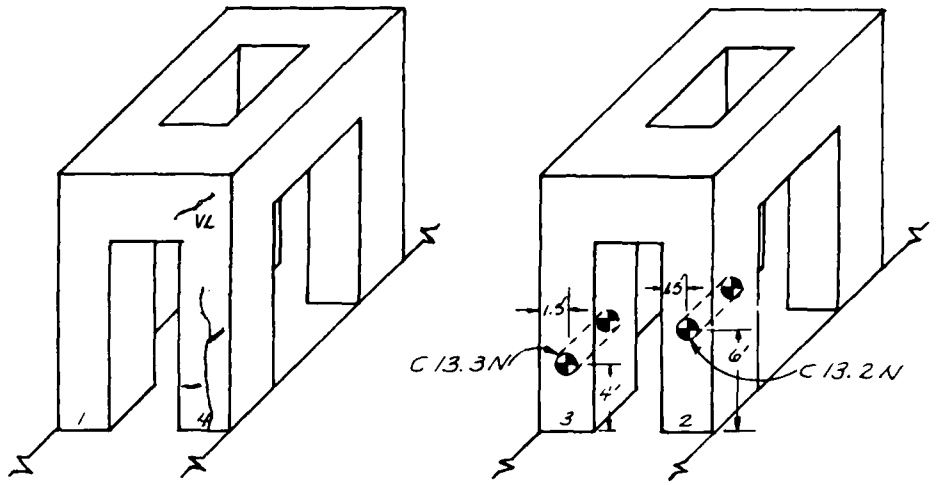
No core taken
Lt damage columns 1 & 4.

VL VERY LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 30

COLUMNS PIER #13

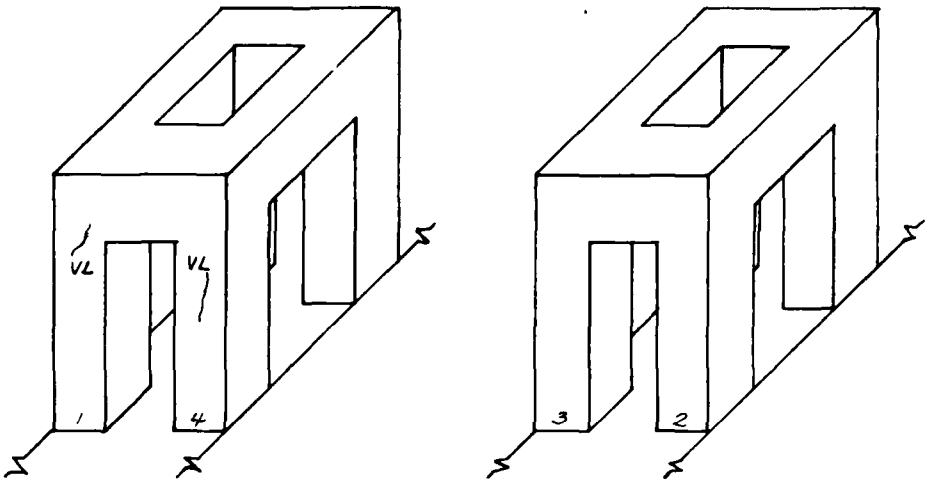


CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
OK	C13.3N	γ, lb/ft^3	157.5	152.2	158.4
		w, pct	4.8	4.4	4.4
		Vp, fps	15,333	15,134	15,073
		q_u, psi	9,770	9,280	10,310
		E, $\times 10^6$ psi	5.04	5.55	5.34
		ν	0.25	0.19	0.18

VL VERY LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

COLLIMNS PIER #14



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

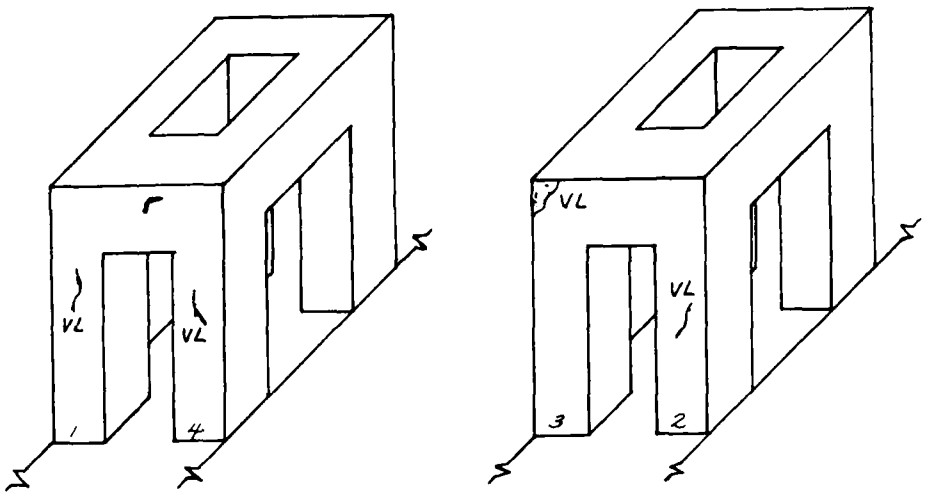
No core taken.
Very light columns 1 & 4.

VL VERY LIGHT MODERATE SEVERE

SCALE ⅛" = 1'

PLATE 32

COLUMNS PIER #15



LOOKING UPSTREAM

LOOKING DOWNSTREAM

CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE

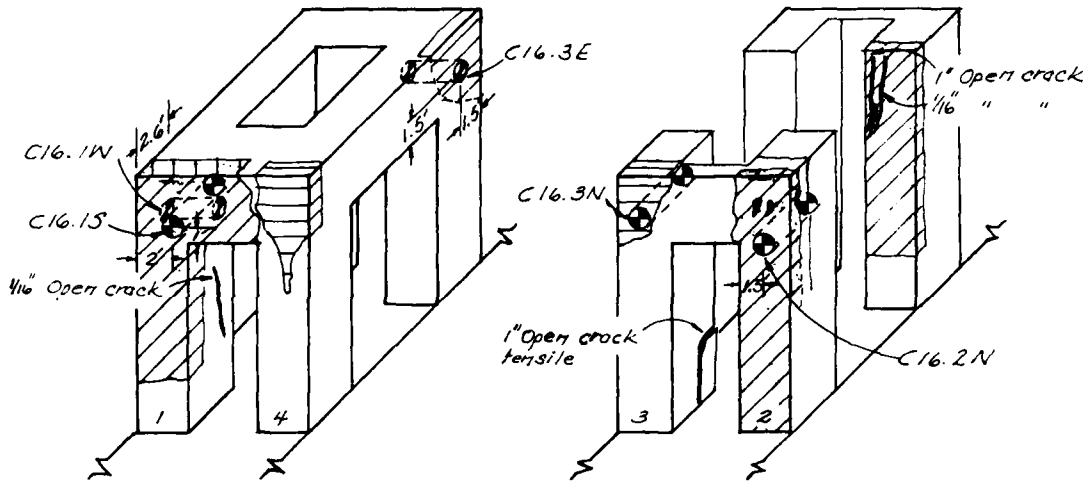
No core taken.
All columns very light damage to concrete.

VL VERY LIGHT MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 33

COLUMNS PIER #16



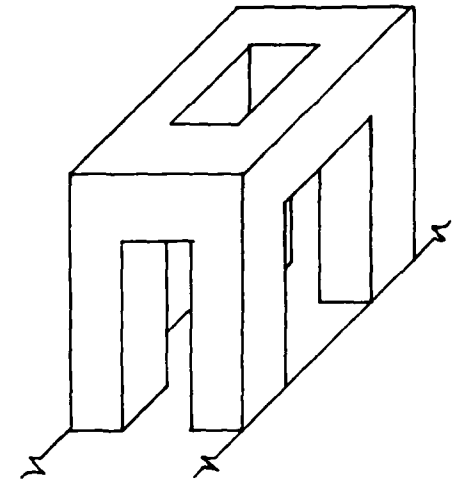
CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
SEV	C16.1S	γ, lb/ft^3	154.0	154.3	149.6
		w, pct	5.3	4.4	5.7
		Vp, fps	2,774	11,111	9,385
		qu, psi	2,240	6,050	2,010
		E, x 10^6 psi	0.18	1.50	0.20
		ν		0.18	
SEV	C16.1W	γ, lb/ft^3	160.3		
		w, pct	4.9		
		qu, psi	5,450		
SEV	C16.2N	No tests due to breaks and rebars.			
MOD	C16.3E	γ, lb/ft^3		154.7	
		w, pct		5.1	
		Vp, fps		14,178	
		qu, psi		6,720	

Up to 1" removed — MODERATE — SEVERE

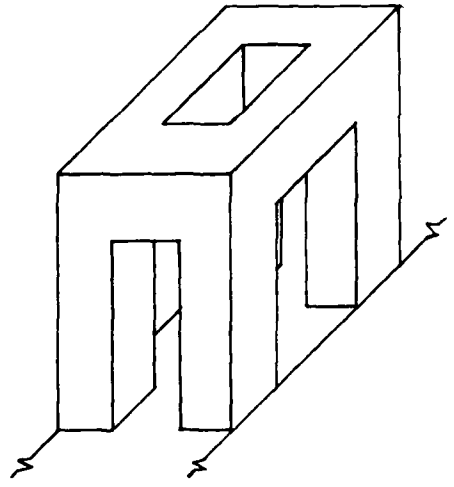
SCALE 1/8" = 1'

PLATE 34

COLUMNS PIER #16 (Cont'd)



LOOKING UPSTREAM



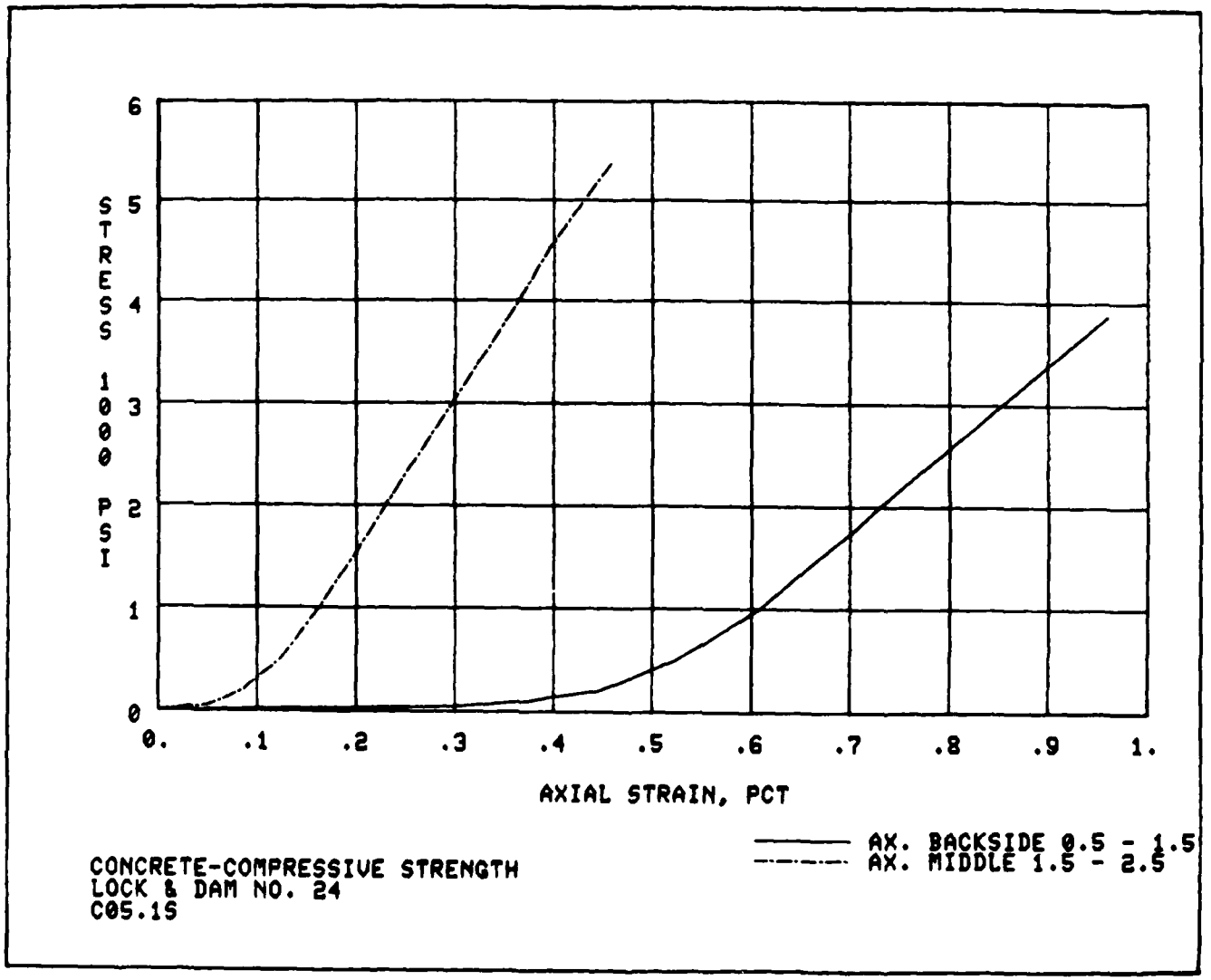
LOOKING DOWNSTREAM

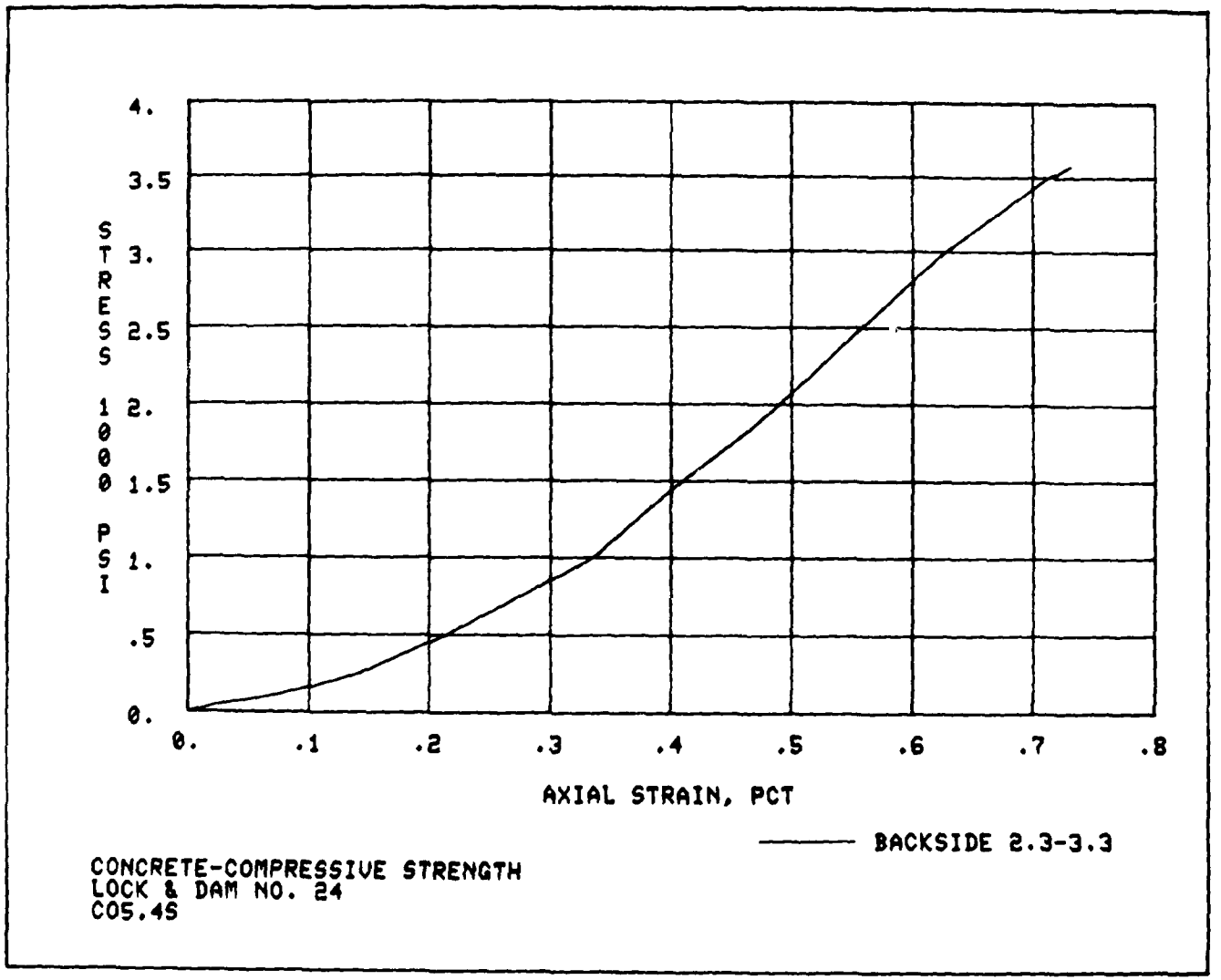
CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES OUTSIDE	MIDDLE	BACKSIDE
MOD	C16.3N	γ, lb/ft^3	154.8	152.6	
		w, pct	5.0	5.6	
		Vp, fps	10,757	13,555	
		qu, psi	6,490	8,250	
		E, x10^6 psi	1.42	3.52	
		ν	0.14	0.18	

OK MODERATE SEVERE

SCALE 1/8" = 1'

PLATE 36

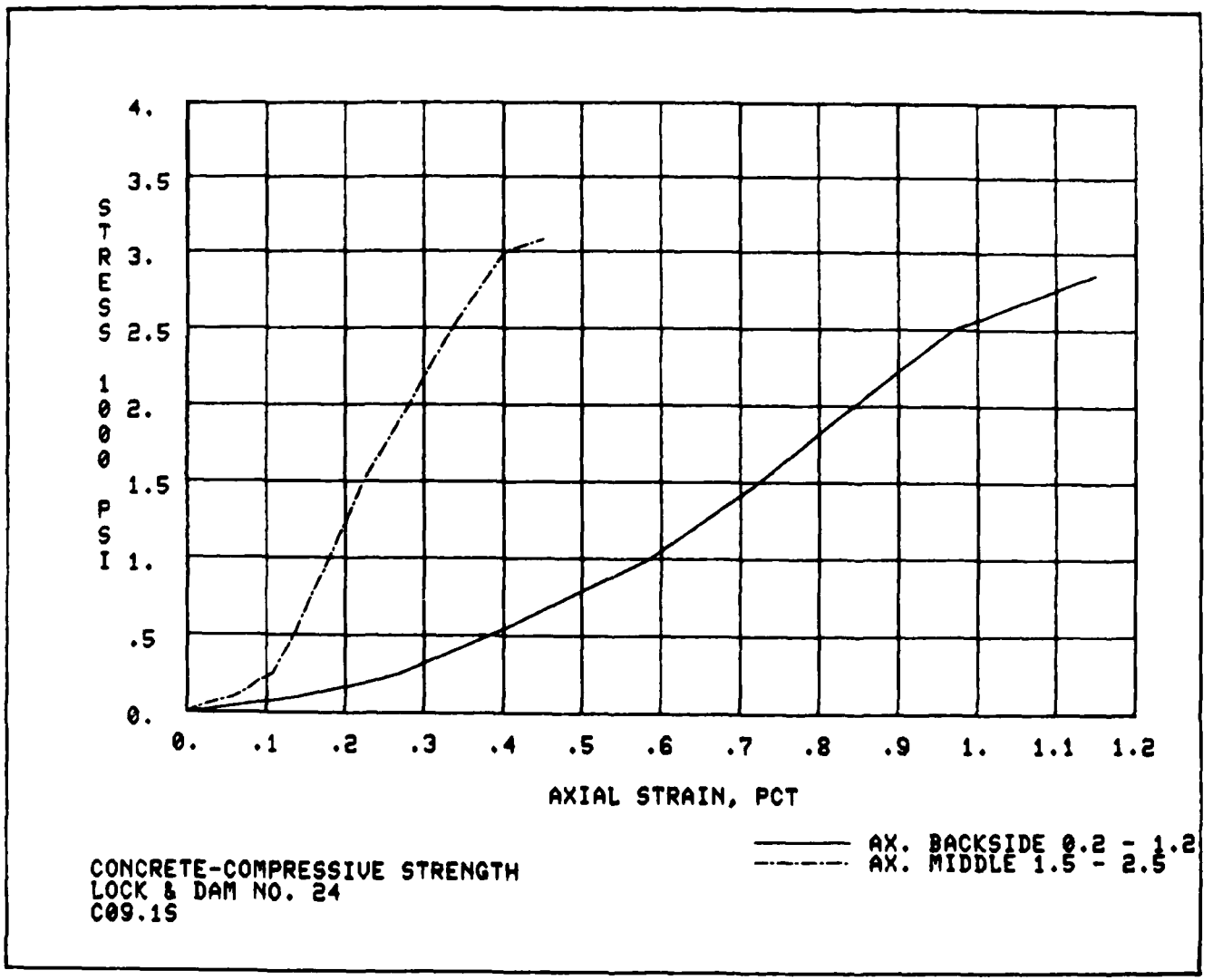

STRESS 1000 PSI
6
5
4
3
2
1
0
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.
AXIAL STRAIN, PCT
AX. BACKSIDE 0.5 - 1.5
AX. MIDDLE 1.5 - 2.5
CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C05.15



CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
CO5.4S

PLATE 37

PLATE 38



CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C09.1S

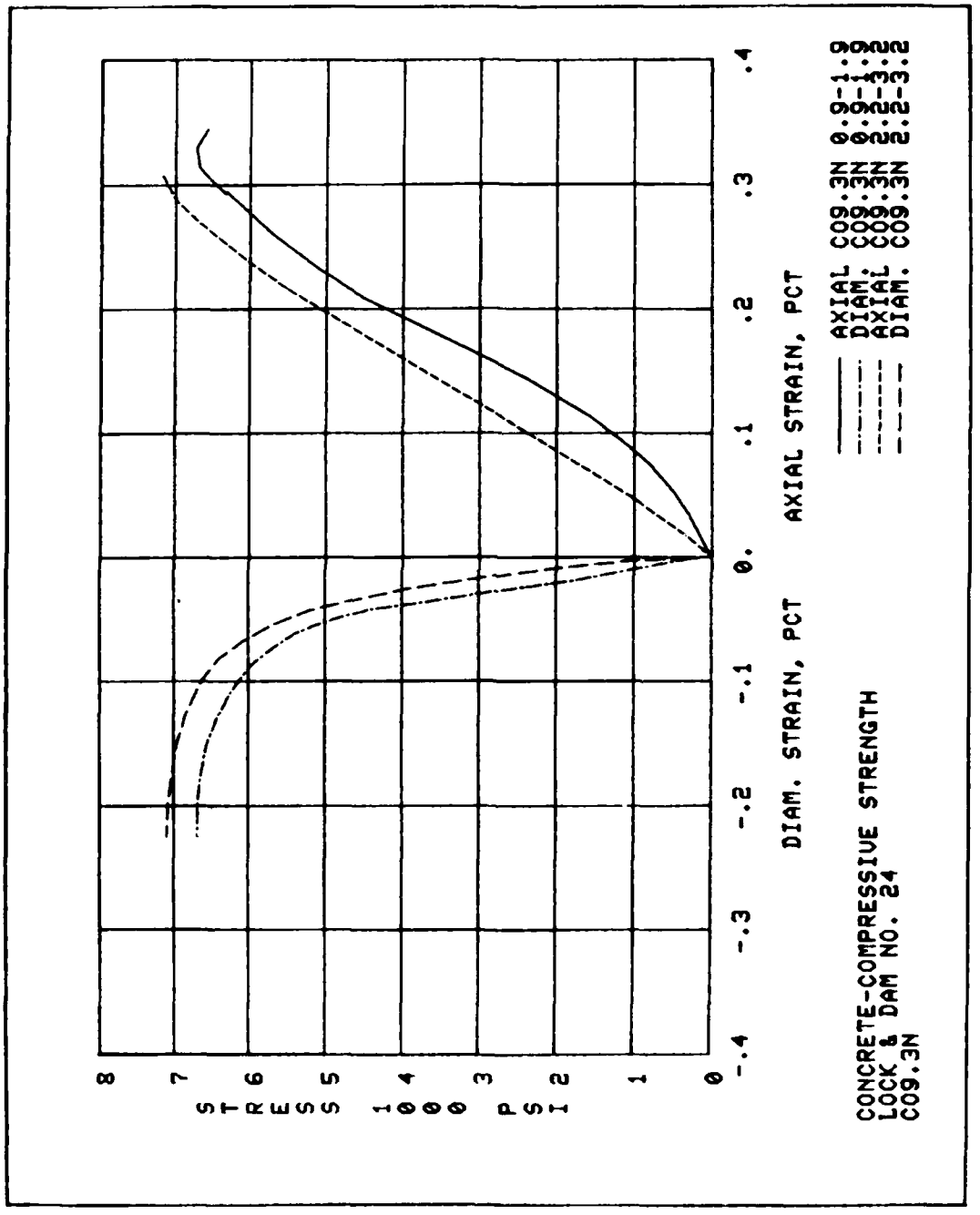

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C09.3N
STRESS 10000 PSI
0
1
2
3
4
5
6
7
8
-.4
-.3
-.2
-.1
0.
.1
.2
.3
.4
DIAM. STRAIN, PCT
AXIAL STRAIN, PCT
AXIAL C09.3N 0.9-1.9
DIAM. C09.3N 0.9-1.9
AXIAL C09.3N 2.2-3.2
DIAM. C09.3N 2.2-3.2

PLATE 39

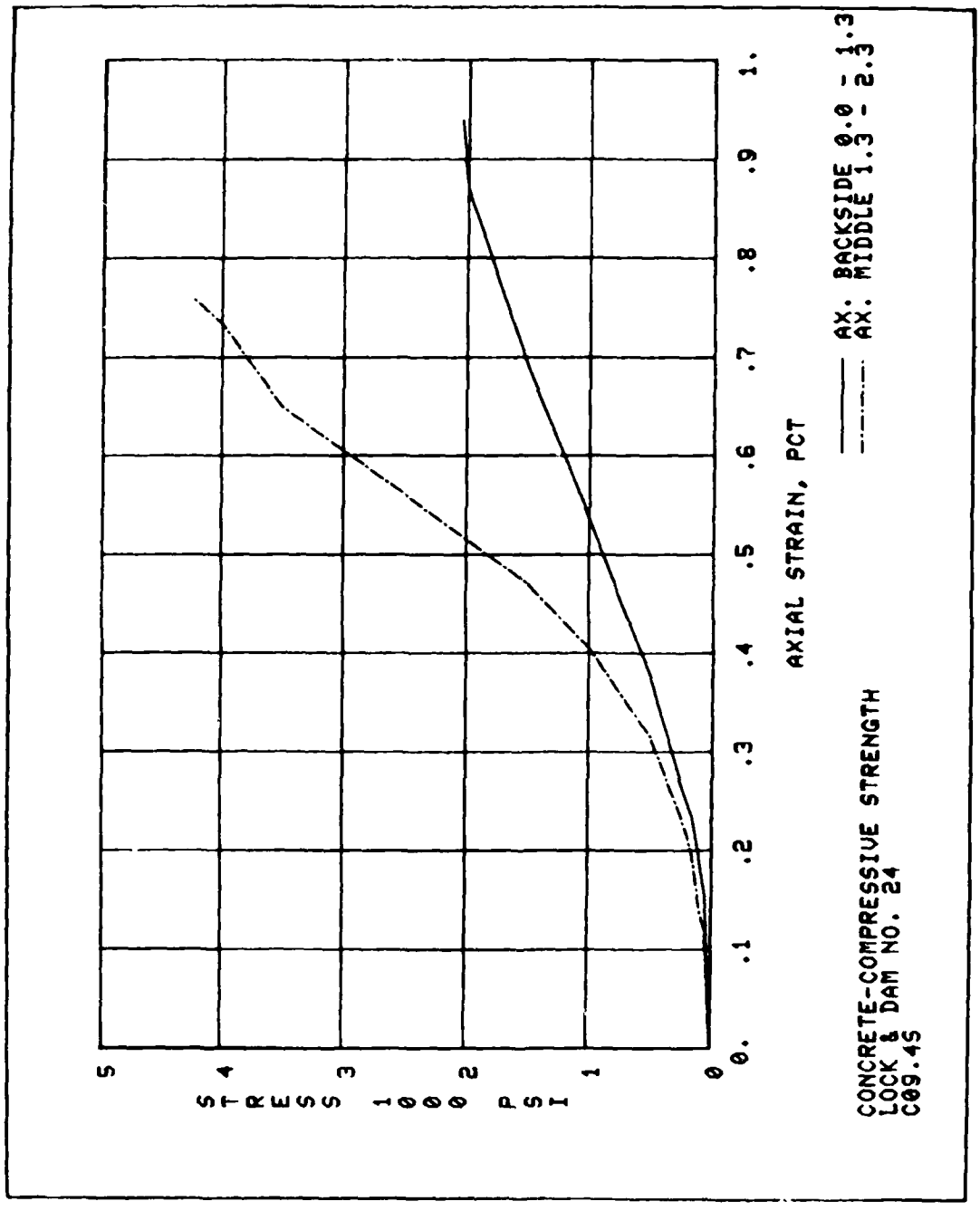

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C09.45
AXIAL STRAIN, PCT
STRESS 1000 PSI
AX. BACKSIDE 0.0 - 1.3
AX. MIDDLE 1.3 - 2.3
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.
0
1
2
3
4
5

PLATE 40

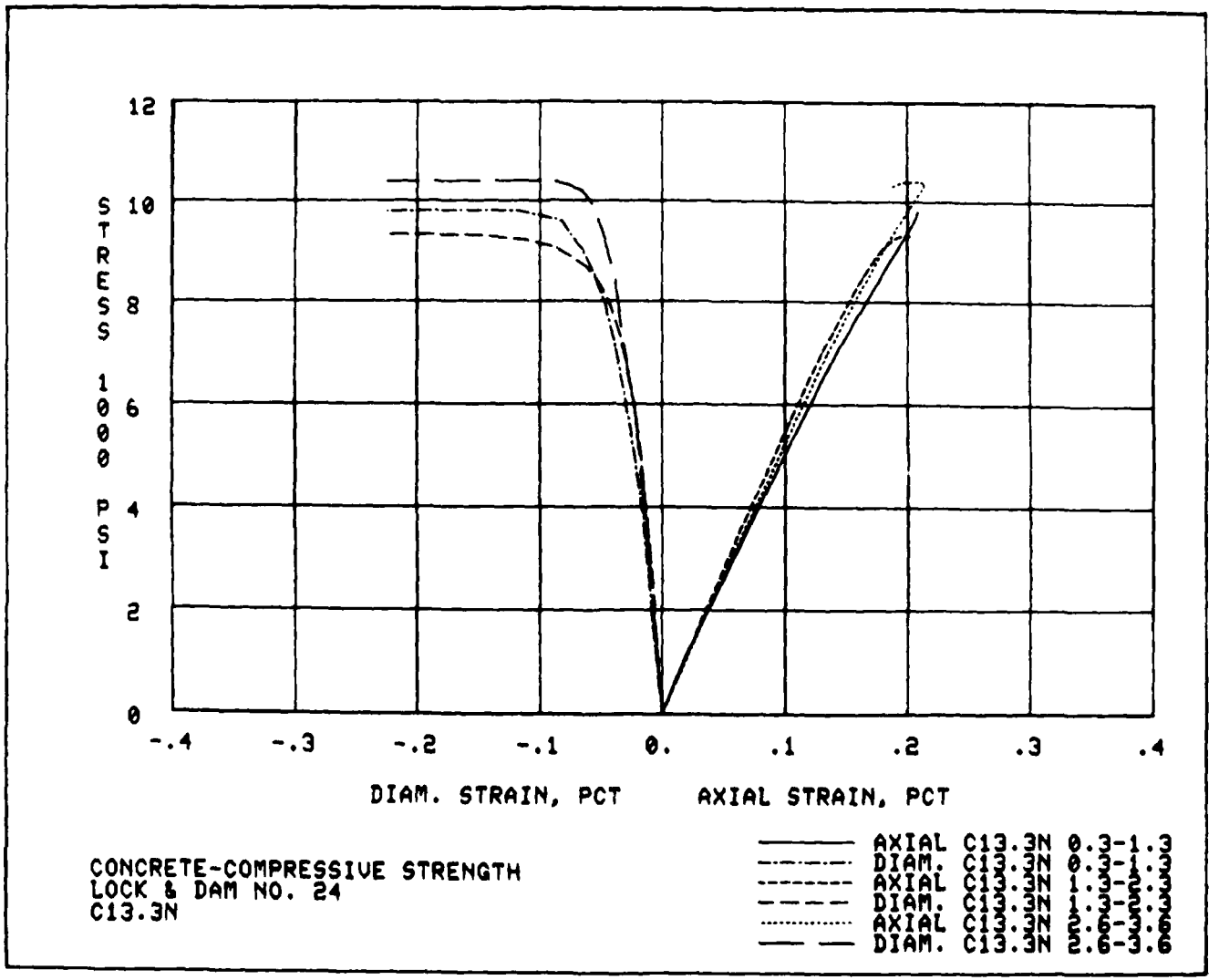

12
10
8
6
4
2
0
STRESS 1000 PSI
-.4
-.3
-.2
-.1
0.
.1
.2
.3
.4
DIAM. STRAIN, PCT
AXIAL STRAIN, PCT
CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C13.3N
AXIAL C13.3N 0.3-1.3
DIAM. C13.3N 0.3-1.3
AXIAL C13.3N 1.3-2.6
DIAM. C13.3N 1.3-2.6
AXIAL C13.3N 2.6-3.6
DIAM. C13.3N 2.6-3.6

PLATE 41

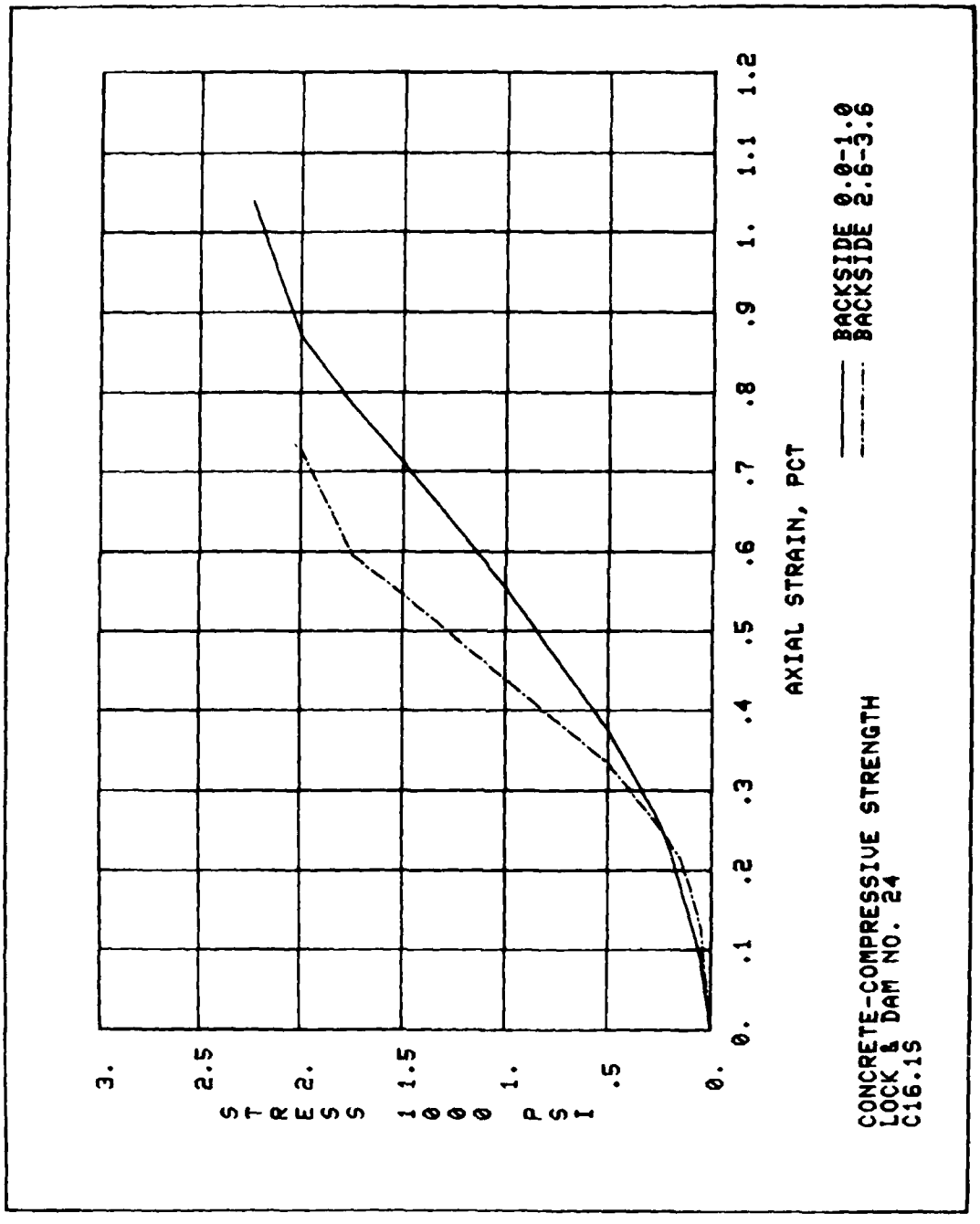

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C16.1S
STRESS 1000 PSI
3.
2.5
2.
1.5
1.
.5
0.
0. .1 .2 .3 .4 .5 .6 .7 .8 .9 1. 1.1 1.2
AXIAL STRAIN, PCT
BACKSIDE 0.0-1.0
BACKSIDE 2.6-3.6

PLATE 42

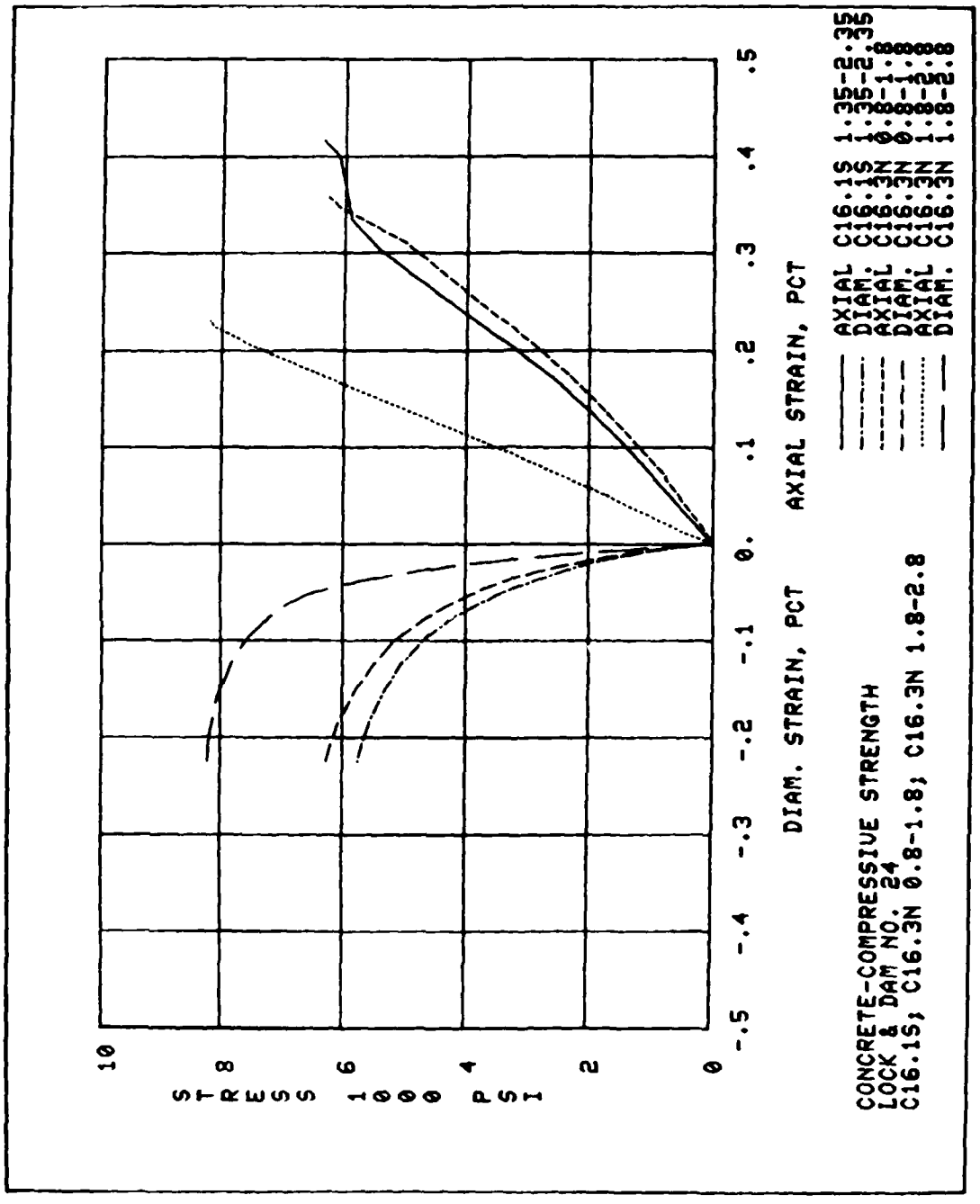
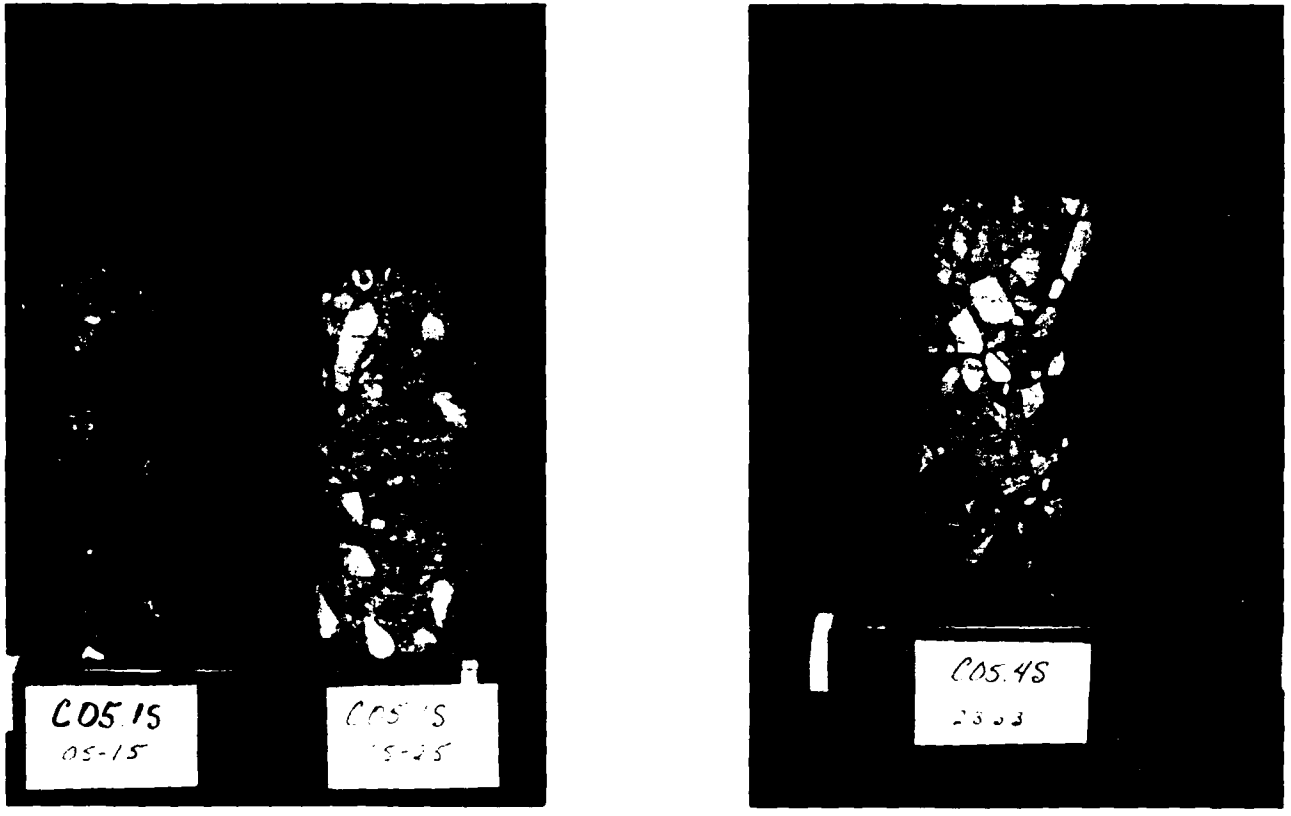
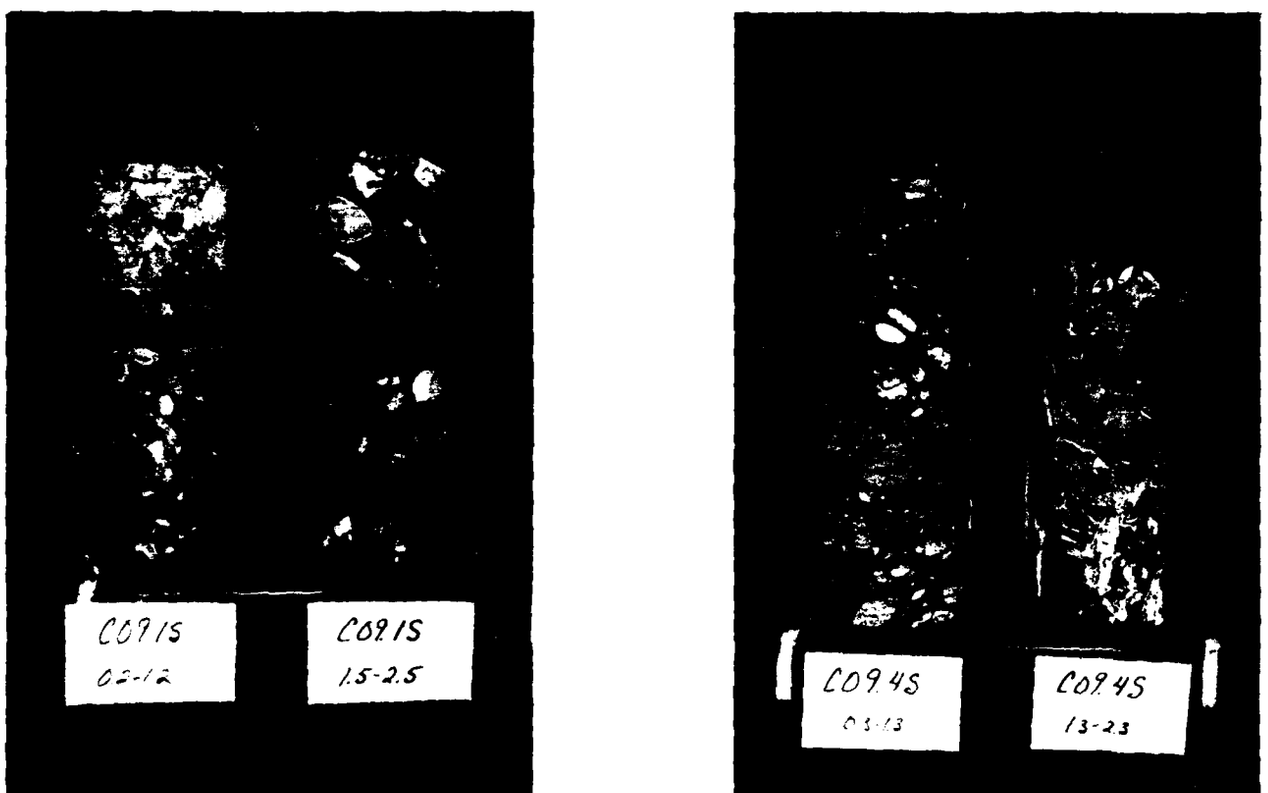

CONCRETE-COMPRESSIVE STRENGTH
LOCK & DAM NO. 24
C16.1S; C16.3N 0.8-1.8; C16.3N 1.8-2.8
AXIAL C16.1S 1.35-2.35
DIAM. C16.1S 1.35-2.35
AXIAL C16.3N 0.8-1.8
DIAM. C16.3N 0.8-1.8
AXIAL C16.3N 1.8-2.8
DIAM. C16.3N 1.8-2.8
DIAM. STRAIN, PCT
AXIAL STRAIN, PCT
STRESS 1000 PSI
10
8
6
4
2
0
-.5
-.4
-.3
-.2
-.1
0.
.1
.2
.3
.4
.5

PLATE 43

PLATE 44

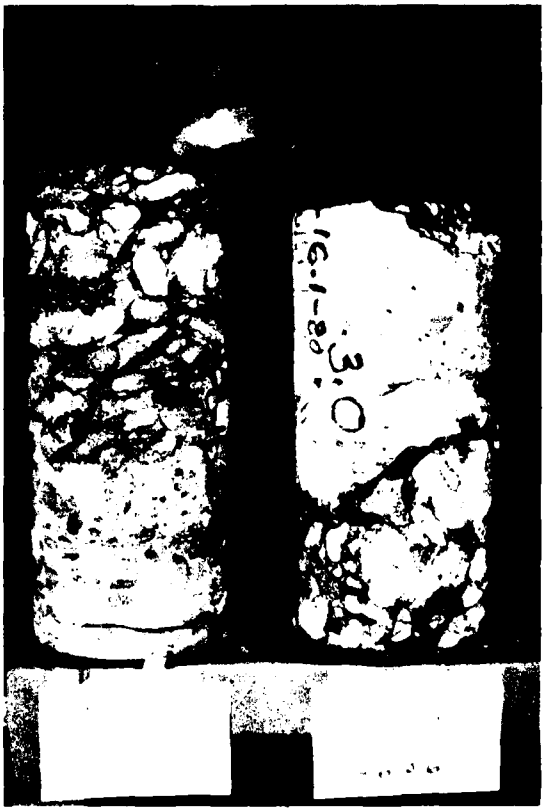


Photographs showing damaged and undamaged concrete cores selected for compressive strength testing; SWES C05.1S and SWES C05.4S



Photographs of damaged concrete cores selected for compressive strength testing;
SWES C09.1S and SWES C09.4S

PLATE 45



Photograph of SWES C16.1S showing damaged concrete core representing the outside and backside of column No. 1 on pier 16

APPENDIX A: TYPICAL PHOTOGRAPHS SHOWING DAMAGED CONCRETE

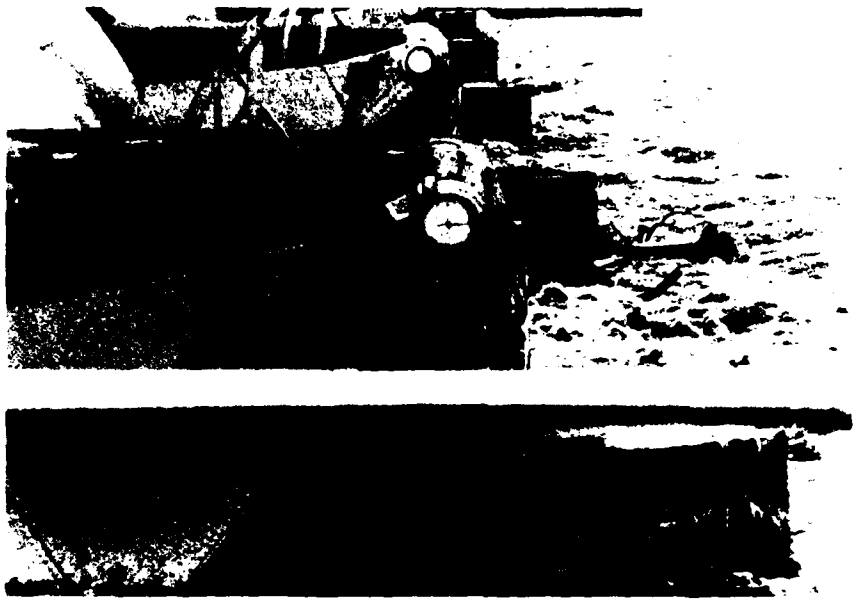


Photo 1. Looking across dam from pier No. 1. Typical cracking pattern with exudation downstream of trunnion pin, pier No. 2

Photo 2. Looking upstream from pier No. 1. Moderately deteriorated concrete on service bridge support column, pier No. 2

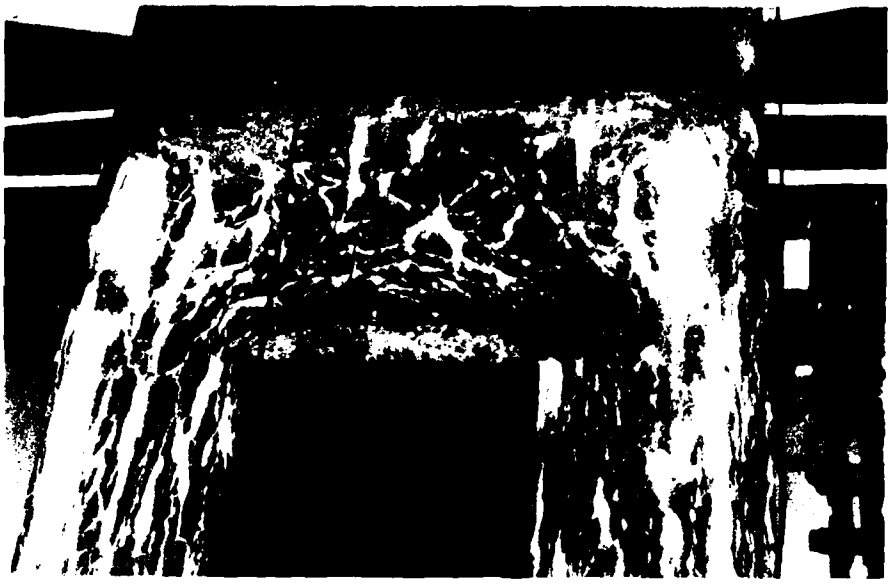


Photo 3. Looking at downstream faces of service bridge support columns, pier No. 9. Typical crack pattern and exudation of severe deterioration

Photo 4. Looking downstream on left dam abutment pier No. 16

Photo 5. Looking downstream, left dam abutment pier No. 16. Structural crack high on downstream column. Crack +1-in. wide

Photo 6. Looking downstream, left dam abutment pier No. 16. Structural crack low on upstream column diagonal to column shown in Photo 5

Photo 7. Close up of crack shown in Photo 6. Note large aggregates as well as concrete matrix is fractured

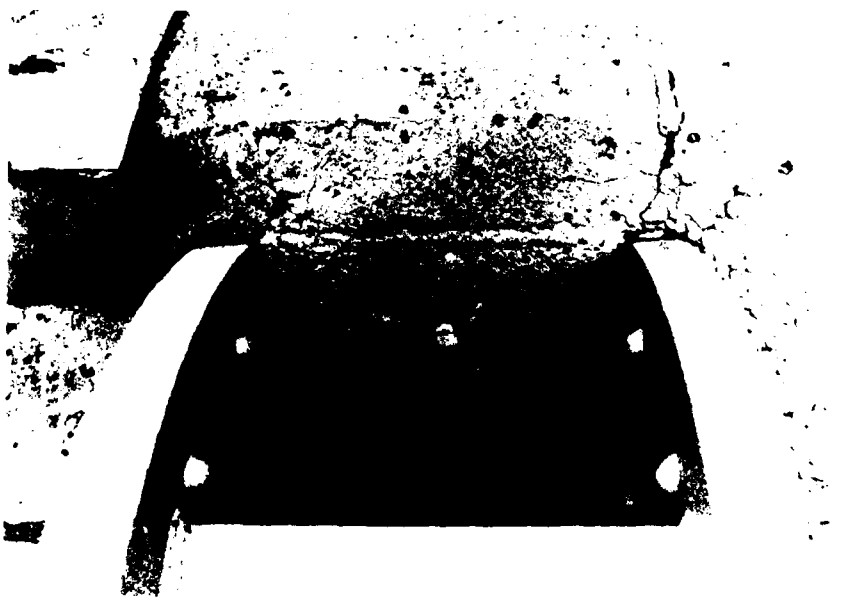


Photo 8. Looking upstream at trunnion shaft area. Typical crack pattern where anchorage collars extend from concrete

Photo 9. Looking upstream at trunnion shaft area. Note wetted area of concrete next to anchorage collar

Photo 10. Looking downstream at trunnion shaft area. Portions of anchorage steel and reinforcing steel exposed by excavating the surrounding concrete

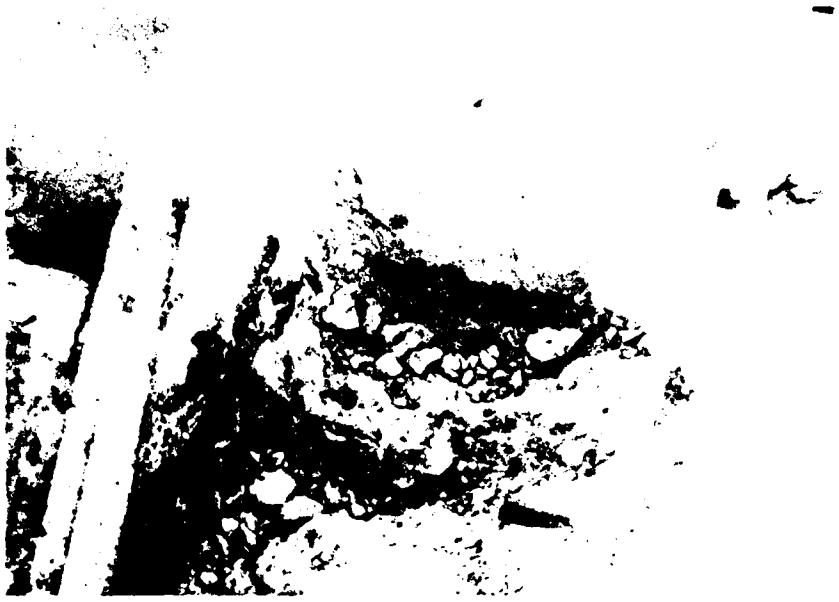


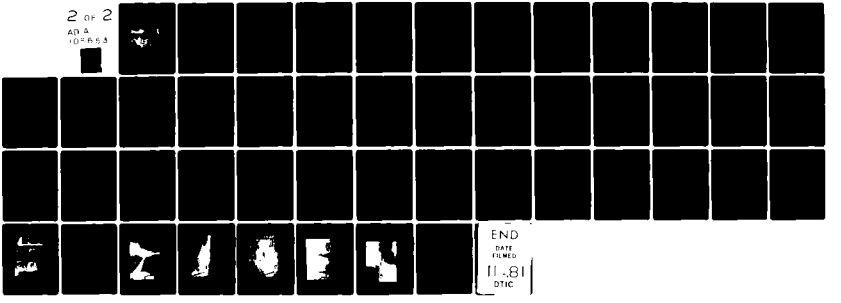
Photo 11. Close up of trunnion shaft anchorage collar, note minor rusted collar steel

Photo 12. Excavation carried deeper. Note minor rusting on anchorage collar steel and cross member steel plate

AD-A105 653 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/2
CONDITION SURVEY, REPAIR AND REHABILITATION, LOCK AND DAM NUMBE--ETC(U)
AUG 81 R L STOWE, H T THORNTON

UNCLASSIFIED WES/MP/SL-81-21 NL

2 OF 2
AD A 105653



END
DATE FILMED
11-81
DTIC

Photo 13. Looking upstream at cross member steel plate in foreground and anchorage collar in the background partially uncovered

APPENDIX B: FIELD CORE LOGS

Hole No. SNCS-C16.38-BC

DRILLING LOG

Division: St Louis 4/6

Installation: Lock and Dam No 24 — Sheet 1 of 1 sheets

1. Project: Lock + Dam No. 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: C.E. N.C.E.S.
4. Hole No. (As shown on drawing title and file number): SNCS-C16.38-BC
5. Name of Driller: H McNamara
6. Direction of Hole: ☐ Vertical ☑ Inclined 90° Deg. From Vert.
7. Thickness of Overburden: /
8. Depth Drilled into Rock: 30'
9. Total Depth of Hole: /
10. Size and Type of Bit: 6" See Below
11. Datum for Elevation Shown (Ft. or MSL): MSL
12. Manufacturer's Designation of Drill: Electric Rig - Long Drill
13. Total No. of Over-burden Samples Taken: Disturbed / Undisturbed
14. Total Number Core Boxes: ONE
15. Elevation Ground Water: —
16. Date Hole: Started 20 November 80 Completed 20 November 80
17. Elevation Top of Hole: 469 C
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Mark S. Hinton

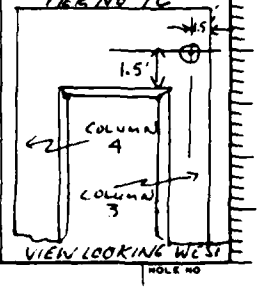
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	Core Recovery (e)	Box or Sample No (f)	Remarks (Drilling time, water loss, depth of weathering, etc.; if significant) (g)
4690	00		CRACKS - CLOSED			Run No. 1 20 Nov 80
			NB			EL — Run 3.0
			HAIRLINE CRACK			Began 1000 Rec 3.0
4690	10					End 1113 Loss —
			CONCRETE.	100%	Box 1	Time 73 min Gain —
			MB			Drl time 70 min
						Hyd press —
4690	20					Water press MED
						RPM Slow
						Drl Action Smooth
						Water ret Brown
						Remarks
4690	30		Run No. 1 ROD = 88.3%		3.0	

Concrete Physical Properties
Same - Concrete is in fair condition. Upper foot is weathered with hairline cracks and moderate reaction product —

Diamond Bit No
81PC130
81PC169

Legend
- Concrete
- Hairline Crack
- NB. : Natural Break
- MB. : Machine Break

Location



ENG FORM 1836 MAR 71 Previous editions are obsolete. (TRANSLUCENT)

Project: — Hole No: —

Hole No. SWG-P04.1-60

DRILLING LOG	Division: St. Louis, Mo	Installation: Lock + Dam #24	Sheet 2 of 2 Sheets
1. PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (MSL or MLW)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE: STARTED / COMPLETED	
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
444.0	10.0	Δ	RUN #5 RQD-100%			Run #5 Run 1.65' Rec 1.65' Loss — Gain — Drl time 60 min Hyd press 500# Water press — SPM 75 Drl Action Smooth Water ret Brown Remarks
443.0	11.0	Δ				
442.0	12.0	NB	1/2"-45°-WEATHERED - BLACK DISCOLORATION ON THE SURFACE OF BREAK - OILY APPEARANCE AND SMELL	100%	Box 3	
441.0	13.0	MB	RUN #6 RQD-100%			Run #6 4 November 60 Run 3.1' Rec 3.1' Loss — Gain — Drl time 285 min Hyd press 500# Water press — SPM 75 Drl Action Smooth Water ret Brown Remarks
440.0	14.0	MB	RUN #7			Run #7 Run 0.2' Rec 0.2' Loss — Gain — Drl time 78 min Hyd press 500# Water press — SPM 70 Drl Action Smooth Water ret Brown Remarks

CONCRETE - BROWNISH GREY IN COLOR, NATURAL AGGREGATE - SITE, SAND TO COARSE GRAVEL (2") WITH THE MAJORITY OF THE AGGREGATE RUNNING FROM ¼" TO ¾". SHAPE, ANGULAR TO ROUNDED WITH MAJORITY BEING ROUNDED IN SHAPE. ORGIN - GLACIAL OR RIVER, TYPE, IGN. SED, + META. WITH HIGH PERCENTAGE OF CHERTS, GRANITES. CONDITIONS - V. LITTLE TO NO REACTION PRODUCT AND OCCURING AT SHALLOW DEPTHS. GENERAL CONDITION APPEARS GOOD —— NATURAL FRACTURING OF CONCRETE AT 11.5' AND 6.4'. CONCRETE DISCOLORED AT 11.5'. MATERIAL HAS AN OIL RESIDUE ON SURFACE OF BREAK.

LEGEND

[20] - Concrete
MB-Machine Break
NB-Natural Break

Bit No:
RO1B158
RO1B154

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT HOLE NO.

Hole No. SWES-P04-1-BC

DRILLING LOG | Division: St Louis, Mo. | Installation: Lock & Dam #24 | Sheet 1 of 2 sheets

1. Project: Locks Dam #24
2. Location (Coordinates or Station): Pier No. 4 - ℄ = 30' from U/S face of upper
3. Drilling Agency: CEWES — Pier Surface
4. Hole No. (As shown on drawing title and file number): SWES-P04-1-BC
5. Name of Driller: A McNamara
6. Direction of Hole: ☒ Vertical ☐ Inclined ____ deg. from vert.
7. Thickness of Overburden: 13.7'
8. Depth Drilled into Rock
9. Total Depth of Hole
10. Size and Type of Bit: 6x7 4" - Str Flush Tube
11. Datum for Elevation Shown (MSL or MLW): MSL
12. Manufacturer's Designation of Drill: Acker
13. Total No. of Overburden Samples Taken: Disturbed ____ Undisturbed ____
14. Total Number Core Boxes: Three
15. Elevation Ground Water: ____
16. Date Hole: Started 30 October 80 Completed 4 November 80
17. Elevation Top of Hole: 1540'
18. Total Core Recovery for Boring: 99.3%
19. Signature of Inspector: Joseph B. Dunbar

Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) (g)
1540	00					Run #1 30Oct - 31Oct WL — 1.95' Began 2:00 - 5/16 Run 1.95 End 7:30 to 9:00 Loss — Time 120min Gain — Drl time 270min Hyd press 200 psi Water press — RPM 70± Drl Action Smooth Water ret Brown Remarks Starting Bit changed B-13
1530	10		¼" Re-bar	100%		
			Concrete Lo'			
			Run #1 RQD = 100%		Box 1	
1520	20					Run #2 WL — Run 1.95' Began 9:10 Rec #1.95' End 10:40 Loss — Time 90min Gain — Drl time 90min Hyd press 250 Water press — RPM 70± Drl Action Smooth Water ret Brown Remarks —
1510	30		Concrete Lo'	100%		
			Run #2 RQD = 100%		Box 1	
1500	40				3.9'	
			Concrete Lo'	0.0%		
			Run #3		Box 2	
1490	50					Run #3 WL Run 1.2 Began 10:50 Rec 00 End 11:45 Loss 1.2 Time 55min Gain — Drl time 55min Hyd press 800 psi Water press — RPM 70± Drl Action Smooth Water ret Brown Remarks —
1480	60					
		NS	∠ = 45°		Box 2	
			∠ = 45° Natural fracturing	133%		
1470	70	NS				
			Concrete Lo'			
1460	80					Run #4 WL — Began 11:55 Run 5.6' End 3:45 Rec 4.8 Time 230min Loss — Drl time 220min Gain 1.2' Hyd press 800 psi Water press — RPM 70± Drl Action Smooth Water ret Brown Remarks
			Run #4 RQD = 85.4%		8.4'	
1450	90					
			Concrete	100%	Box 3	
1440	100					

ENG FORM 1836 MAR 71 — Previous editions are obsolete. (TRANSLUCENT)

Project: ____ Hole No.: ____

Hole No. SWES-P091-80

DRILLING LOG | Division: St Louis, Mo. | Installation: Lock + Dam #24 | Sheet 1 of 2 sheets

1. PROJECT: Luck + Dam #24
2. LOCATION (Coordinates or Station): See Page Two
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): SWES-P091-80
5. NAME OF DRILLER: A McNamara
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 14.2'
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT: See Page Two
11. DATUM FOR ELEVATION SHOWN (MSL or USL): M.S.L
12. MANUFACTURER'S DESIGNATION OF DRILL: Acker
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED _____ UNDISTURBED _____
14. TOTAL NUMBER CORE BOXES: Four
15. ELEVATION GROUND WATER: —
16. DATE HOLE: STARTED 28 October 80 COMPLETED 30 October 80
17. ELEVATION TOP OF HOLE: 454.0
18. TOTAL CORE RECOVERY FOR BORING: 97 2/3 %
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
454.0	0.0		~3½' Riprap Run #1 RQD-100%	100%	Box 1	Run #1 28 Oct 80 WL — Run 0.9' Began 1:30 Rec 0.9' End 3:48 Loss — Time 138 min Gain — Drl time 138 min Hyd press 750 to 700 PSI Water press — RPM 70±
453.0	1.0					Drl Action Smooth Water ret Brown Remarks - Changed Bits - Starting B&L
452.0	2.0		CONCRETE	88.1%	Box 1	Run #2 29 October 80 WL — Run 3.1' Began 9:06-5.2 Rec 1.85' End 8:00-9:10 Loss 0.25' Time 144 min Gain — Drl time 194 min Hyd press 300±
451.0	3.0		NO & NB SURFACE PARTIALLY STAINED Run #2 RQD-100%			Water press — RPM 70±
450.0	4.0		CONCRETE Run #3 RQD-100%	/	Box 1	Drl Action Smooth Water ret Brown-Starting B&L Remarks
449.0	5.0		NB		5.0	Run #3 1.45' WL — Run — Began 9:30 Rec — End 11:00 Loss 1.45 Time 90 min Gain — Drl time 90 min Hyd press 300±
448.0	6.0		CONCRETE	162%	Box 2	Water press — RPM 75±
447.0	7.0		Run #4 RQD-100%		7.2	Drl Action Smooth Water ret Brown Remarks Continued with Starting B&L to make room for 5' B&L - Don't Break
446.0	8.0		CONCRETE	100%	Box 3	Run #4 WL — Run 3.45' Began 11:15 Rec 4.95' End 2:50 Loss — Time 215 min Gain 1.90 Drl time 215 Hyd press 300-500 Water press — RPM 75±
445.0	9.0					Drl Action Smooth Water ret Brown Remarks
444.0	10.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. SWES-P04 2-60

DRILLING LOG | Division: St Louis Mo. | Installation: Lock & Dam No. 24 | Sheet 1 of 1 Sheets

1. Project: Lock and Dam No. 24
2. Location (Coordinates or Station): See below
3. Drilling Agency: CE, W.E.S.
4. Hole No. (As shown on drawing title and file number): SWES-P04 2-60
5. Name of Driller: A. McNamara
6. Direction of Hole: ☐ Vertical ☑ Inclined 9.0° Deg. From Vert.
7. Thickness of Overburden: 64'
8. Depth Drilled into Rock
9. Total Depth of Hole
10. Size and Type of Bit: Calyx face below
11. Datum for Elevation Shown (USGS or Mean): MSL
12. Manufacturer's Designation of Drill: Electric — Colp Drill
13. Total No. of Overburden Samples Taken: Disturbed — Undisturbed —
14. Total Number Core Boxes: Two
15. Elevation Ground Water
16. Date Hole: Started 28 Nov 60 Completed 28 Nov 60
17. Elevation Top of Hole: 448.0'
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Joseph B. Dick

Elevation	Depth	Legend	Classification of Materials (Description)	% Core Recovery	Box or Sample No.	Remarks
448.0	0					Run No 1 28 Nov 60 WL — Run 1.35 Began 12:30 Rec 1.35 End 1:30 Loss — Time 60 min Gain — Drl time 60 min Hyd press — Water press MSL RPM 300± Drl Action Smooth Water ret Brown Remarks
		MB	Concrete	100%	Box 1	
448.0	10					
		NB	Run No 1 RQD = 70.4%			
448.0	20		Concrete	100%	Box 1	
448.0	30					Run No 2 WL Began 1:35 Run 2.2 End 3:45 Rec 2.2 Time 100 min Loss — Drl time 100 min Gain — Hyd press — Water press MSL RPM 300± Drl Action Smooth Water ret Brown Remarks
		NB	Run No 2 RQD = 100%	355		
448.0	40		Concrete: Fair condition — upper portion is very poor. Numerous breaks & cracks, along with moderate amounts of reaction product. Physical properties same as other W.E.S borings	100%	Box 2	
448.0	50					Run No 3 WL Began 3:30 Run 2.85 End 5:40 Rec 2.85 Time 130 min Loss — Drl time 130 min Gain — Hyd press — Water press MSL RPM 300± Drl Action Smooth Water ret Brown Remarks
448.0	60					
		MB/NB	Run No 3 RQD = 85.7%			

Diamond Bits

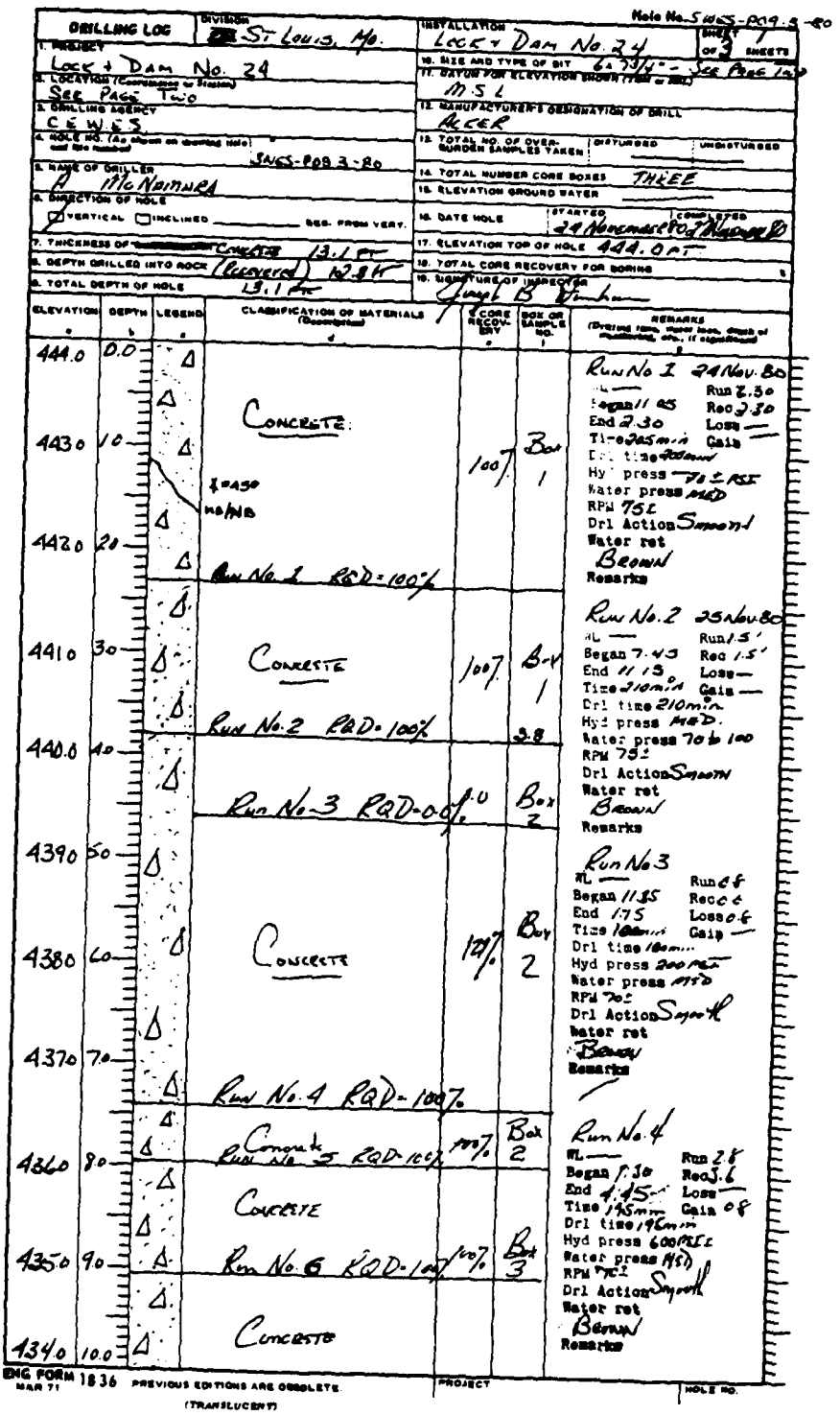
79PN0437
79PB6897

LEGEND

- 4 - Concrete
- ☐ - Hairline cracks
- MB - Machine break
- NB - Natural break

LOCATION

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.



DRILLING LOG — Division: St. Louis, Mo. — Hole No. SWS-809-3-80

1. PROJECT: Lock + Dam No. 24
2. LOCATION (Coordinates or Station): See Page Two
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): SWS-809-3-80
5. NAME OF DRILLER: P McNamara
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: Concrete 13.1 ft
8. DEPTH DRILLED INTO ROCK (Recovered): 12.9 ft
9. TOTAL DEPTH OF HOLE: 13.1 ft
10. INSTALLATION: Lock + Dam No. 24
11. SIZE AND TYPE OF BIT: 6 7/8" - See Page Two
12. DATUM FOR ELEVATION SHOWN (MSL or MLW): MSL
13. MANUFACTURER'S DESIGNATION OF DRILL: ACKER
14. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED ____ UNDISTURBED ____
15. TOTAL NUMBER CORE BOXES: THREE
16. ELEVATION GROUND WATER: ____
17. DATE HOLE: STARTED 24 November 80 COMPLETED 27 November 80
18. ELEVATION TOP OF HOLE: 444.0 ft
19. TOTAL CORE RECOVERY FOR BORING: 98%
20. SIGNATURE OF INSPECTOR: Lloyd B Brown
SHEET 1 OF 3 SHEETS

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
444.0	0.0					Run No 1 24 Nov 80 WL — Run 2.5' Began 11 45 Rec 2.5' End 2.30 Loss — Time 225 min Gain — Drl time 225 min Hyd press 70 ± PSI Water press MED RPM 75± Drl Action Smooth Water ret Brown Remarks
443.0	1.0		Concrete I=450 HS/NB	100%	Box 1	
442.0	2.0		Run No 1 RQD=100%			
441.0	3.0		Concrete	100%	Box 1	Run No.2 25 Nov 80 WL — Began 7.45 Run 1.5' End 11 15 Rec 1.5' Time 210 min Loss — Drl time 210 min Gain — Hyd press MED. Water press 70 to 100 RPM 75± Drl Action Smooth Water ret Brown Remarks
440.0	4.0		Run No.2 RQD=100%		3.8	
439.0	5.0		Run No-3 RQD-0.0%	10%	Box 2	Run No 3 WL — Began 11 55 Run 0.6 End 1 15 Rec 0.6 Time 180 min Loss 0.6 Drl time 180 min Gain — Hyd press 200 PSI Water press MED RPM 70± Drl Action Smooth Water ret Brown Remarks
438.0	6.0		Concrete	12%	Box 2	
437.0	7.0		Run No.4 RQD=100%			
436.0	8.0		Concrete Run No 5 RQD 100%	100%	Box 2	Run No.4 WL — Began 1.10 Run 2.8 End 4.15 Rec 3.6 Time 185 min Loss — Drl time 180 min Gain 0.8 Hyd press 600 PSI Water press MED RPM 70± Drl Action Smooth Water ret Brown Remarks
435.0	9.0		Concrete Run No. 6 RQD-100%	100%	Box 3	
434.0	10.0		Concrete			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. SWCS-P09-1 BC

DRILLING LOG | DIVISION | INSTALLATION: Lock + Dam #24 | SHEET 2 OF 9 SHEETS

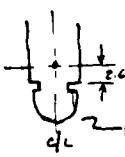
1. PROJECT
2. LOCATION (Coordinates or Stations)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title) and file number
5. NAME OF DRILLER
6. DIRECTION OF HOLE — ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE — STARTED — COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIAL (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
444.0	100		RUN #5 RQD-100%		Box 3 10.4	RUN #5 — Ru. 2.7 Began 3:15 Rec 2.7 End 5:20 Loss — Time 125 min Gain — Drl time 125 min Hyd press 500-700± Water press — RPM 50 to 75± Drl Action Smooth Water ret Brown Remarks —
443.0	110					
442.0	120		CONCRETE	89.5%	Box 4	RUN #6 30 October 80 WL — Run 3.8' Began 7:30 Rec 3.4' End 11:30 Loss 0.4 Time 240 min Gain — Drl time 240 min Hyd press 500-700 Water press — RPM 50-75± Drl Action Smooth Water ret Brown Remarks LEFT LAST 0.4' IN HOLE
		NB				
441.0	130					
		NB	CONCRETE HAS ODD APPEARANCE — BREAKS HAS "INNER PLUG" — POSSIBLY TWO POURS			
		MB			13.8	
440.6	140		RUN #6 RQD = 88.0%			

CONCRETE: - BROWNISH GRAY IN COLOR, NATURAL AGGREGATE - SIZE - SAND TO COARSE GRAVEL (2") WITH MAJORITY OF AGGREGATE RUNNING FROM 1/2" TO 1 1/2". SHAPE - ANGULAR TO ROUNDED - 5-20% ANGULAR WITH REST BEING ROUNDED - ORIGIN - GLACIAL OR RIVER - TYPE - IGNEOUS - SEDIMENTARY - + METAMORPHIC, HIGH PERCENTAGE OF CHERTS AND GRANITES - CONDITION - V. LITTLE TO NO REACTION PRODUCT VISIBLE, GENERAL CONDITION APPEARS TO BE GOOD. ODD BREAK AT 13.4'

BITS
80 1B FSR
80 1B S4

LOCATION



LEGEND
C: - CONCRETE
NB - NATURAL BREAK
MB - MACHINE BREAK

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. SAESPC95-66

DRILLING LOG	DIVISION	INSTALLATION: Lock & Dam No 24	SHEET 7 OF 8 SHEETS
1. PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title) and file number		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE: STARTED / COMPLETED	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING %	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Descriptions) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCRETE: GRAYISH BROWN IN COLOR WITH NATURAL AGGREGATE. THE AGGREGATE RANGES IN SIZE FROM 1/8" TO 2" MAX WITH 80% RUNNING FROM 1/4" TO 1". THE SHAPE OF AGGREGATE IS ANGULAR TO ROUNDED WITH 90% BEING ROUNDED OR SEMI-ROUND. THE CONCRETE IS IN GOOD CONDITION, IN THAT IT LACKS HAIRLINE BREAKS, CRACKS, AND SIGNIFICANT AMOUNTS OF REACTION PRODUCT. ALL BREAKS IN CORE ARE THE RESULT OF MACHINE ACTION (BREAKS AT 10.5' & 15' ARE NATURAL BREAKS). DRILL TIMES FOR EACH RUN INDICATE A VERY "TOUGH," HARD CONCRETE.			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. SWT-A9-3 &

DRILLING LOG | Division | Installation: York Dam No. 24 | Sheet 2 of 3 Sheets

1. Project
2. Location (Coordinates or Station)
3. Drilling Agency
4. Hole No. (As shown on drawing title) and file number
5. Name of Driller
6. Direction of Hole: ☐ Vertical ☐ Inclined _____ Deg. From Vert.
7. Thickness of Overburden
8. Depth Drilled into Rock
9. Total Depth of Hole
10. Size and Type of Bit
11. Datum for Elevation Shown (Ton or MSL)
12. Manufacturer's Designation of Drill
13. Total No. of Overburden Samples Taken: Disturbed / Undisturbed
14. Total Number Core Boxes
15. Elevation Ground Water
16. Date Hole: Started / Completed
17. Elevation Top of Hole
18. Total Core Recovery for Boring %
19. Signature of Inspector

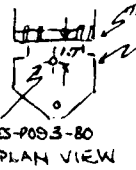
Elevation	Depth	Legend	Classification of Materials (Description)	% Core Recovery	Box or Sample No.	Remarks (Drilling time, water loss, depth of weathering, etc., if significant)
434.0	10C		Run No. 7 RQD = 100%			Run No. 5 26 Nov 80 WL — Run 0.55 Began 7:40 Rec 0.55 End 9:30 Loss — Time 110 min Gain — Drl time 110 min Hyd press 400 PSI Water press N/D RPM 80 ℓ Drl Action Smooth Water ret Brown Remarks
433.0	11.0	MB	Concrete:	100%	Box 3	
432.0	12.0	NB	Run No. 8 RQD = 100%			Run No. 6 WL — Run 1.1' Began 9:35 Rec 1.1' End 2:15 Loss — Time 150 min Gain — Drl time 145 min Hyd press 1000 PSI Water press N/D RPM 80–100 ℓ Drl Action Smooth Water ret Brown Remarks
431.0	13.0		Run No. 9 RQD = 66%		Box 3	
			Run No. 9 WL — Began 11:45 End 2:00 Time 135 min Drl time 130 min Hyd press 300–500 Water press N/D RPM 80 ℓ Drl Action Smooth Water ret Brown Remarks Change B.t.s Run 0.8 Rec 0.1 Loss 0.7 Gain —	Run No. 10 WL — Began 2:30 End 4:15 Time 165 min Drl time 165 min Hyd press 500 PSI Water press N/D RPM 80 ℓ Drl Action Smooth Water ret Brown Remarks Run 0.4' Rec 1.0' Loss 0.3' Gain 0.7'	138'
			Run No. 7 WL — Began 12:45 End 1:45 Time 240 min Drl time 240 min Hyd press 400 PSI Water press N/D RPM 80 ℓ Drl Action Smooth Water ret Brown Remarks Run 1.45 Rec 1.45 Loss — Gain —	
			Run No. 8 27 Nov 80 WL — Began 8:30 End 11:30 Time 180 min Drl time 175 min Hyd press 500 PSI Water press N/D RPM 55 ℓ Drl Action Smooth Water ret Brown Remarks Run 1.2' Rec 1.2' Loss — Gain —	

Hole Left

LEGEND

△ Concrete
M.B Machine Break
N.B Natural Break

LOCATION



PLAN VIEW

Diamond Bits
- 80 PC 11 G2
- R.S 80 RC 169
- 80 B 153

ENG FORM 1836 MAR 71 — Previous editions are obsolete — Project — Hole No.

Hole No. SWES-P151-80

DRILLING LOG	DIVISION St Louis, Mo	INSTALLATION Lock + Dam #24	SHEET 1 OF 5 SHEETS

1. PROJECT Lock + Dam #24	10. SIZE AND TYPE OF BIT 6x7¾ - See Page
2. LOCATION (Coordinates or Station) ¢ of Pier - 30' US of ¢ of 721' US Pier	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) SWES-P151-80	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER A McNamara	14. TOTAL NUMBER CORE BOXES 11
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER ?
	16. DATE HOLE: STARTED 21 October 1980; COMPLETED 27 October 1980
7. THICKNESS OF OVERBURDEN 0	17. ELEVATION TOP OF HOLE 454.0'
8. DEPTH DRILLED INTO ROCK 41.1	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 41.1 Concrete	19. SIGNATURE OF INSPECTOR Joe Dunbar by BLS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
454.0	0.0	Δ	3/4 Rebar; Concrete; Run #1 RQD-100%	100%	Box 1	Run 1.75; Began 8:00; Rec 1.75; End 10:15; Loss —; Time 135min; Gain —; Drl time 135min; Hyd press 200-400 PSI; Water press —; RPM 75-150 ?; Drl Action Smooth; Water ret Brown. Remarks
453.0	1.0					
452.0	2.0	Δ	Concrete; Run #2 RQD-100%	100%	Box 1	Run #2; WL; Run 1.75'; Began 10:30; Rec 1.75; End 11:30; Loss —; Time 60min; Gain —; Drl time 60min; Hyd press 400 ?; Water press —; RPM 150 ?; Drl Action Smooth; Water ret Brown; Remarks (1) Changed Bits
451.0	3.0		MB			
450.0	4.0	Δ	Concrete - Grey Brown in color, Natural River-Glacial Agg. Sed. Ign. Meta - Angular to Rounded with majority being Rounded and size distribution is from sand and fine gravel, to a very coarse gravel. Slight reaction product along with reaction rims on gravel were visible, as well as a pourous appearance to the concrete. Breaks are through the softer agg. and occurring around the harder material.	4.75; 100%	Box 1; Box 2	Run #3; WL; Run 4.65'; Began 1:30; Rec 4.65'; End 4:40; Loss —; Time 190min; Gain —; Drl time 150min; Hyd press 200-300 ?; Water press —; RPM 70-150; Drl Action Smooth; Water ret Brown; Remarks
449.0	5.0		NB			
448.0	6.0		← Hairline Crack			
447.0	7.0		NB			
446.0	8.0		Run #3 RQD-100%			Run #4 22 October 80
445.0	9.0	Δ	Concrete; ← Hairline Crack; NB	85%	Box 2	WL; Run 1.75; Began 5:00-5:20; Rec 1.5; End 7:30-9:30; Loss 0.25; Time 140min; Gain —; Drl time 140min; Hyd press 200-500 ?; Water press; RPM 150 ?; Drl Action Smooth; Water ret Brown; Remarks
444.0	10.0	Δ	Run #4 RQD-83%		4.6; Box 3	Left 0.25 in hole

ENG FORM MAR 71 1836 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. SWES-P09.2-80

DRILLING LOG	Division: Sr Louis, Mo.	Installation: Lock and Dam # 24	Sheet 1 of 1 sheets
1. Project: Lock & Dam No 24		10. Size and type of bit: 6" - B.C. No 7918691	
2. Location (Coordinates or Station): Pier No. 9 - 4' up from vertical face of U/S portion of Pier #9 — Lewes under trunnion pin.		11. Datum for elevation shown (USGS or NGS): MSL	
3. Drilling agency: Lewes		12. Manufacturer's designation of drill: Sprague and Henwood	
4. Hole no. (As shown on drawing title and file number): SWES-P09.2-80		13. Total no. of overburden samples taken: Disturbed — Undisturbed —	
5. Name of driller: A McNamara		14. Total number core boxes: Two	
6. Direction of hole: ☐ Vertical ☒ Inclined 90° deg. from vert		15. Elevation ground water: —	
7. Thickness of overburden:		16. Date hole: Started 6 November 80 Completed 6 November 80	
8. Depth drilled into rock: 5.9'		17. Elevation top of hole: 448.0 Center of Boring	
9. Total depth of hole:		18. Total core recovery for boring: 100 %	
		19. Signature of inspector: Joseph B. Bunker	

Elevation	Depth	Legend	Classification of Materials (Description)	Core Recovery	Box or Sample No.	Remarks (Drilling time, water loss, depth of weathering, etc., if significant)
448.0	0.0		HAIRLINE CRACKS - CLOSED			Run #1 6 November 80 Wt — Run 2.90 Began 8.43 Rec 1.90 End 10.50 Loss 0.5 Time 127 min Gain — Drl time 112 min Hyd press 60 TO 70 PSI Water press Low RPM 50± Drl Action Smooth Water ret Brown Remarks Starting Bbl.
			WEDGE OF CONCRETE IS MISSING			
			HAIRLINE CRACKS - CLOSED	79.2%	Box 1	
448.0	1.0		UPPER SURFACE OF CONCRETE IS PITTED AND V MUCH WEATHERED - WEATHERED CONDITION OCCURS TO 0.9 FT WHERE CONDITION IMPROVES - MODERATE REACTION PRODUCT IN			
448.0	2.0	NB	RUN #1 WEATHERED AREA			
			RQD=63.1%			Run #2 Wt — Run 2.60' Began 11.15 Rec 2.90' End 1.30 Loss 0.20' Time 135 min Gain 0.50' Drl time 135 min Hyd press 60 TO 80 PSI Water press Low RPM 70± Drl Action Smooth Water ret Light Brown Remarks
448.0	3.0		CONCRETE - GOOD CONDITION		Box 1	
448.0	4.0			115%		
		MB	RUN #2 RQD=100%		4.8'	
448.0	5.0		CONCRETE	122.2%	Box 2	Run #3 Wt — Run 0.90' Began 2.05 Rec 1.10' End 3.38 Loss 0.0' Time 93 min Gain 0.20' Drl time 93 min Hyd press 120 PSI Water press Low RPM 75± Drl Action Smooth Water ret Brown Remarks
			RUN #3 RQD=100%			
448.0	6.0		BORING INTERSECTED SWES-P09.1-80			

[A Δ] - Concrete
~·~ - Hairline cracks
MB - Machine break
NB - Natural break

Concrete is same as encountered in other W.E.S Borings— Aggregate; type, & size, and shape is same

ENG FORM 1836 MAR 71 — Previous editions are obsolete (TRANSLOCENT) — Project — Hole No.

Hole No. WES-P151-80

DRILLING LOG	DIVISION	INSTALLATION: Lock & Dam #24	SHEET 3 OF 5 SHEETS
1. PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE: STARTED / COMPLETED	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING	%
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO f	REMARKS (Drilling time, water loss, depth of weathering, etc.; if significant) g
434.0	20.0		Run # 8		20.15	23 Oct. – 24 Oct 1980 Run #9 WL — Run 4.25 Began 7:15-7:30 Rec 4.25 End 7:50-12:00 Loss — Time 355 MIN Gain — Drl time 340 MIN Hyd press 250-300 Water press — RPM 70 I Drl Action Smooth Water ret Brown Remarks Cuttings B.TS
433.0	21.0		Concrete	100%	Box 6	
432.0	22.0					
		NB				
431.0	23.0					Run #10 WL — Began 1:10 Run 2.75 End 3:50 Rec 2.75 Time 140 MIN Loss — Drl time 140 MIN Gain — Hyd press 150 Water press — RPM 50 I Drl Action Smooth Water ret Brown Remarks
430.0	24.0		Run # 9 RQD = 100%		24.4	
429.0	25.0		Concrete	100%	Box 7	Run #11 250 to 50 WL — Run 5.6' Began 3:57-5:08 Rec 5.6' End 7:42-11:40 Loss — Time 278 MIN Gain — Drl time 278 MIN Hyd press 200 Water press — RPM 70 I Drl Action Smooth Water ret Brown
428.0	26.0					
427.0	27.0		Run # 10 RQD = 100%		27.15	
426.0	28.0		Concrete	100%	Box 8	Run 12 WL Began 11:45 Run 4.1 End 3:20 Rec 4.1 Time 215 MIN Loss — Drl time 215 MIN Gain — Hyd press 200 I Water press — RPM 70 I Drl Action Smooth Water ret Below U Remarks
425.0	29.0					
424.0	30.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. SWES-1151-80

DRILLING LOG	Division	Installation: Lock & Dam #24	Sheet 3 of 5 Sheets
1. Project		10. Size and Type of Bit	
2. Location (Coordinates or Stations)		11. Datum for Elevation Shown (TBM or MSL)	
3. Drilling Agency		12. Manufacturer's Designation of Drill	
4. Hole No. (As shown on drawing title and file number)		13. Total No. of Overburden Samples Taken: Disturbed / Undisturbed	
5. Name of Driller		14. Total Number Core Boxes	
6. Direction of Hole: ☐ Vertical ☐ Inclined ____ Deg. From Vert.		15. Elevation Ground Water	
7. Thickness of Overburden		16. Date Hole: Started / Completed	
8. Depth Drilled into Rock		17. Elevation Top of Hole	
9. Total Depth of Hole		18. Total Core Recovery for Boring: %	
		19. Signature of Inspector	

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) g
444.0	10.		Concrete Lock		Box 3	Run #5 WL — Run 1:30 Began 10:30 Rec 1.55 End 1:39 Loss — Time 189 min Gain 0.25 Drl time 180 min Hyd press 250-300 L Water press — RPM 1563 Drl Action Smooth Water ret Brown Remarks
443.0	11.0		Run #5 RQD: 100%			
442.0	12.0		Concrete		Box 3	
441.0	13.0	NB		100%	13.2	Run #6 WL — Run 3.3 Began 2 30 Rec 3.3 End 5 36 Loss — Time 180 min Gain — Drl time 170 min Hyd press 300-600 L Water press — RPM 70 L Smooth Drl Action Water ret Brown Remarks
440.0	14.0		Run #6 RQD=100%			
439.0	15.0	NB	Concrete	100%		
			Run #7 RQD=80%			Run #7 23 September 80
438.0	16.0		Concrete		Box 4	WL — Run Began 8:30 Rec End 11 50 Loss Time 180 min Gain Drl time 180 min Hyd press 800 L Water press — RPM 851 Drl Action Smooth Water ret Brown — Changed Bits Remarks
437.0	17.0	NB			17.65	Run #8 WL — Run 4.5 Began 12:35 Rec 4.5 End 4:50 Loss — Time 135 min Gain — Drl time 135 min Hyd press 750 L Water press — RPM 70 Drl Action Smooth Water ret Brown
436.0	18.0			100%	Box 5	
435.0	19.0					
434.0	20.0		RQD 100%		20.15	

ENG FORM 1836 MAR 71 — Previous editions are obsolete (TRANSLUCENT) — Project — Remarks — Hole No.

Hole No. SWES-PIS 2-80

DRILLING LOG | DIVISION: St Louis M/D | INSTALLATION: Lock + Dam No 24 | SHEET 1 OF 1 SHEETS

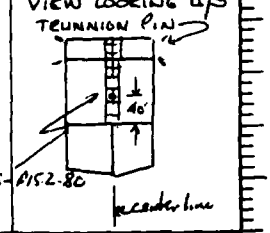
1. PROJECT: Lock + Dam No. 24
2. LOCATION (Coordinates or Station): See Below
3. DRILLING AGENCY: C.E.W.E.S.
4. HOLE NO. (As shown on drawing title and file number): SWES-PIS.2-80
5. NAME OF DRILLER: A. McNamara
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK 6.55'
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT 6 5/8 - See Below
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: SPRACE AND HENWOOD
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
14. TOTAL NUMBER CORE BOXES: TWO
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 7 Nov. 80 / COMPLETED
17. ELEVATION TOP OF HOLE: 448.1'
18. TOTAL CORE RECOVERY FOR BORING: 100%
19. SIGNATURE OF INSPECTOR: Joseph B. Dunn

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
448.1	0.0		WEATHERED			Run No 1 - 7 Nov 80 WL — Began 8:10 End 10:30 Time 140 min Drl time 135 min Hyd press 75± Water press Low RPM 75± Drl Action Smooth Water ret Brown Remarks Destroyed Hydraulic Pump
448.1	1.0	MB	Run No. 1 - RQD.	100%	Box 1	Run 1.50' Rec 1.50' Loss — Gain —
448.1	3.0		CONCRETE.	100%		Run No 2 - 2 Dec 80 WL — Began 9:50 End 1:30 Time 340 min Drl time 230 min Hyd press 70-100± Water press MED RPM 75± Drl Action Smooth Water ret Brown Remarks - CHANGED BITS
448.1	4.0		Run No 2 RQD = 100%		4.15	Run 2.70 Rec 2.70 Loss — Gain —
448.1	5.0		CONCRETE: GOOD CONDITION, PHYSICAL PROPERTIES SAME AS PREVIOUS BORINGS — VERY LITTLE TO NO R+P AND HAIRLINE CRACKS —	100%		Run No 3 - 3 Dec 80 WL — Began 10:50 End 7:50 - 1:15 Time 315 min Drl time 5 min Hyd press 70 to 100± Water press MED RPM 75± Drl Action Smooth Water ret Brown Remarks
448.1	6.0		Run No 3 RQD = 100%		6.55	Run 2.40 Rec 2.40 Loss — Gain —

DIAMOND BITS
79 AW 4393
79 AB 6877

LEGEND
- Concrete
- Hairline Break
- MB. Machine Break
- NB. Natural Break

LOCATION



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. SWES-SP151-80

DRILLING LOG	DIVISION	INSTALLATION: Lock + Dam #24	SHEET 1 OF 5 SHEETS
1. PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title) and file number		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE: STARTED / COMPLETED	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING: %	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
424.0	30°		RUN #11 RQD=100%		30.75	
423.0	31°					
421.0	32°				Box 9	
		NB	CONCRETE	100%		
420.0	33°					
419.0	34°					RUN #13
			RUN #12 RQD=100%		34.8	WL RUN 0.9
418.0	35°		2" MACHINE BREAK			Began 4.05 REC 0.1
			CONCRETE			End 5:05 Loss 0.8
			RUN #13			Time 63 min Gain —
			3/4" REBAR			Drl time 60 min
417.2	36°				Box 10	Hyd press 700±
						Water press —
						RPM 70±
416.0	37.2					Drl Action Smooth
						Water ret Brown
			CONCRETE			Remarks CAUGHT SLIPPAGE
						RUN #14
						7 October 80
						RUN #14
415.0	38°	NB			37.95	WL — Rm 42
						Began 10:40 Rec 5.0
						End 3:35 Loss —
						Time 295 min Gain 0.8
						Drl time 280 min
					Box 11	Hyd press 700±
						Water press —
414.0	39°					RPM 70±
						Drl Action Smooth
						Water ret Brown
						Remarks
413.0	40°		RUN #14			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. SWES-COS-1W-50

DRILLING LOG | Division: St. Louis, Mo. | Installation: Lock + Dam No 24 | Sheet 1 of 1 sheets

1. Project: Lock + Dam No 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: C E W E S
4. Hole No. (As shown on drawing title and file number): SWES-COS-1W-50
5. Name of Driller: A McNamara
6. Direction of Hole: ☐ Vertical ☒ Inclined 90° deg. from vert.
7. Thickness of Overburden: —
8. Depth Drilled into Rock: 3.1'
9. Total Depth of Hole: —
10. Size and Type of Bit: See Below — 6"
11. Datum for Elevation Shown (MSL or USC&GS): MSL
12. Manufacturer's Designation of Drill: Electric - Core Drill
13. Total No. of Overburden Samples Taken: Disturbed — Undisturbed —
14. Total Number Core Boxes: One
15. Elevation Ground Water: —
16. Date Hole: Started 18 November 80 Completed 18 November 80
17. Elevation Top of Hole: 466.5 ± Center of Boring
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Joseph B Dunham

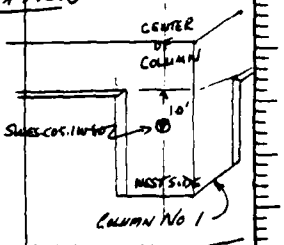
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No (f)	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) (g)
466.5	0.0		~ Broken up Rock No 1 RQD: 0%			Run No 1 18 Nov 80
			SWES-NB			WL — Rec 0.40
			Rebar - ½"			Began 2 20 Rec 0 40
466.5	10					End 2.35 Loss —
			Concrete.	100%	Box 1	Time 15min Gain —
						Drl time 15min
						Hyd press —
466.5	20					Water press NCD
						RPM 300± Smooth
						Drl Action
						Water ret Brown
						Remarks
						Run No 2 Run 2.7'
466.5	30		Rebar - ½" Run No 2 RQD = 100%			Began 3 45 Rec 2.7'
						End 3:50 Loss —
						Time 65min Gain —
						Drl time 65min
						Hyd press —
						Water press NCD
						RPM - 300±
						Drl Action Smooth
						Water ret Brown
						Remarks

Concrete: Physical Properties Same.
Condition of Concrete is Fair.
Ends are weathered with top portion broken up at rebar.
Little to no reaction product is visible —

Diamond Bit No
81PC178
81PC173

Legend
- Concrete
- Hairline Crack
- MB - Machine Break
- NB - Natural Break
- ~ Broken up - Pieces too small to log -

Location



ENG FORM 1836 MAR 71 Previous editions are obsolete (Translucent) | Project | Hole No

Hole No. SMES-C02.2N-80

DRILLING LOG	DIVISION St Louis, Mo	INSTALLATION Lock + Dam No 24	SHEET 1 OF 1 SHEETS
1. PROJECT Lock + Dam No 24		10. SIZE AND TYPE OF BIT Jac Bexta 6x6 1/2"	
2. LOCATION (Coordinates or Station) SEE BELOW		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY C.E.W.E.S		12. MANUFACTURER'S DESIGNATION OF DRILL ELECTRIC - CORE DRILL	
4. HOLE NO. (As shown on drawing title) and this number SMES-C02.2N-80		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —	
5. NAME OF DRILLER A McNamara		14. TOTAL NUMBER CORE BOXES ONE	
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.		15. ELEVATION GROUND WATER —	
7. THICKNESS OF OVERBURDEN /		16. DATE HOLE STARTED 21 Nov 80 COMPLETED 21 Nov 80	
8. DEPTH DRILLED INTO ROCK 3.5'		17. ELEVATION TOP OF HOLE 4686 FT. Gunk Hole	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING 100%	
		19. SIGNATURE OF INSPECTOR Floyd B Wanless	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
4686	00					Run No 1 21 Nov 80
			1¼" Rebar			AL — Rd: 3.5'
4686	10					Began 10 45 Rec 3.5
			½" Rebar			End 11 20 Loss —
						Time 75 Min Gain —
						Drl time 70 Min
						Hyd press —
				100%	Box 1	Water press NED
						RPM 500 F
4686	20		1½" Rebar			Drl Action Smooth
			1¼" Rebar			Water ret (Brown)
						Remarks
			Concrete			
4686	30					
			Run No 1 RQD: 100%		3.5'	

Concrete. Very good condition, no hairline cracks, very little to no reaction products and physical properties same as other WES borings.

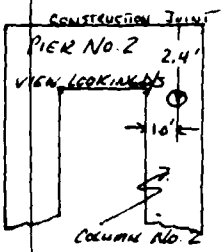
Diamond Bits

79RN429

LEGEND

- Concrete
- Hairline Crack
- MB. Machine Break
- NB. Natural Break

LOCATION



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO

Hole No. SWES-COS 45-80

DRILLING LOG — DIVISION: St. Louis Mo — INSTALLATION: Lock + Dam No 24 — SHEET 1 OF 1 SHEETS

1. PROJECT: Lock + Dam No. 24
2. LOCATION (Coordinates or Station): See Below
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): SWES-COS 45-80
5. NAME OF DRILLER: J. McNamara
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 3.5
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT: 6" Size Below
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: ELECTRIC-CORE DRILL
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED ___ UNDISTURBED ___
14. TOTAL NUMBER CORE BOXES: ONE
15. ELEVATION GROUND WATER: ___
16. DATE HOLE: STARTED 18 Nov 80 COMPLETED 18 Nov 80
17. ELEVATION TOP OF HOLE: 466.5' - CENTER
18. TOTAL CORE RECOVERY FOR BORING: 100%
19. SIGNATURE OF INSPECTOR: Capt B. Hinkson

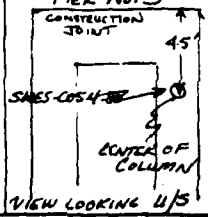
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
466.5	0.0		MATERIAL IN RUN NO 1 IS LOOSE GRAVEL & RUBBLE — CRACKS ARE VISIBLE FROM BORING — RUN No 1. RQD=0.0%	100%	Box 1	Run No. 1 18 Nov 80 WL — Run 0.8' Began 1105 Rec 0.8' End 1115 Lose — Time 10 min Gain — Drl time 10 min Hyd press — Water press MED RPM 300± Drl Action Smooth Water ret Brown Remarks BLOCKED OFF - RUBBLE
466.5	1.0		CONCRETE	100%	Box 1	
466.5	2.0					
466.5	3.0		NO RUN No. 2 RQD= 96.3%	3.50		Run No 2 WL — Run 2.7 Began 1130 Rec 2.7 End 1230 Lose — Time 120 min Gain — Drl time 90 min Hyd press — Water press MED. RPM 300± Drl Action Smooth Water ret Brown Remarks

CONCRETE PHYSICAL PROPERTIES THE SAME — CONDITION IS VERY POOR FROM 0.0 TO 0.8' MATERIAL IS RUBBLE — CONDITION IMPROVING WITH DEPTH — MODERATE REACTION PRODUCT.

DIAMOND BIT NO
81 PC 175

LEGEND
- [4:] CONCRETE
- [-] HAIRLINE CRACK
- MB MACHINE BREAK
- NB NATURAL BREAK

LOCATION



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) — PROJECT — HOLE NO.

Hole No. SNES-COS 15-80

DRILLING LOG | DIVISION: St Louis, Mo | INSTALLATION: Lock + Dam No 24 | SHEET 1 OF 1 SHEETS

1. PROJECT: Lock + Dam No 24	10. SIZE AND TYPE OF BIT: 6 inch - See Below
2. LOCATION (Coordinates or Station): See Below	11. DATUM FOR ELEVATION SHOWN (USGS or MSL): MSL
3. DRILLING AGENCY: CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL: Electric - Core Drill
4. HOLE NO. (As shown on drawing title and file number): SNES-COS.15-80	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —
5. NAME OF DRILLER: A McNamara	14. TOTAL NUMBER CORE BOXES: ONE
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.	15. ELEVATION GROUND WATER: —
7. THICKNESS OF OVERBURDEN:	16. DATE HOLE: STARTED 17 November 1980 COMPLETED 17 November 80
8. DEPTH DRILLED INTO ROCK: 3.5'	17. ELEVATION TOP OF HOLE: 465.5'
9. TOTAL DEPTH OF HOLE:	18. TOTAL CORE RECOVERY FOR BORING: 100%
	19. SIGNATURE OF INSPECTOR: Joseph B Dunbar

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
465.5	0.0		NB/NB Run No 1 RQD- 0.0%			Run No 1 17 Nov 80 — — Run 0.35 Began 12.09 Rec 0.35 End 12.18 Loss — Time 9 min Gain — Drl time 9 min Hyd press — Water press 40 psi RPM 300 r Drl Action Smooth Water ret Brown Remarks Blocked off
465.5	10		½" Rebar			
465.5	20		Concrete	100%	Box 1	
465.5	30		½" Rebar Rebar Steel 1" air			Run No 2 WL Run 3.15 Began 12.25 Rec 3.15 End 1/15 Loss — Time 50 min Gain — Drl time 50 min Hyd press — Water press 40 psi RPM 300 r Drl Action Smooth Water ret Brown Remarks
			Run No 2 RQD- 100%		3.5'	

Concrete Physical Properties

Same — size and shape of Agg, color, etc. Condition of Concrete is Poor. Numerous Hairline cracks and moderate amounts of reaction product in cracked portions of core are visible.

Diamond Bit No

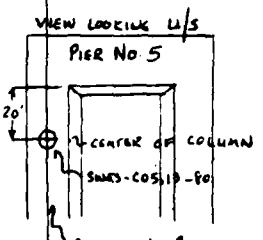
81 PC 175

81 PC 172

LEGEND

- Concrete
- Hairline Crack
- MB Machine Break
- NB Natural Break

LOCATION



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. SWES-C07.3N-80

DRILLING LOG | DIVISION: ST. LOUIS | INSTALLATION: Lock & Dam No 24 | SHEET 1 OF 1 SHEETS

1. PROJECT: Lock + Dam No 24
2. LOCATION (Coordinates or Station): SEE BELOW
3. DRILLING AGENCY: C.E.W.E.S.
4. HOLE NO. (As shown on drawing title) and file number): SWES-C07.3N-80
5. NAME OF DRILLER: A. McNamara
6. DIRECTION OF HOLE: ☐ VERTICAL ☑ INCLINED 90 DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK 3.5
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT: See Below - 6"
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Electric - Core Drill
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: one
15. ELEVATION GROUND WATER —
16. DATE HOLE: STARTED 13 November 80 COMPLETED 15 November 80
17. ELEVATION TOP OF HOLE 464.7
18. TOTAL CORE RECOVERY FOR BORING 100%
19. SIGNATURE OF INSPECTOR: Hugh B. Dunn

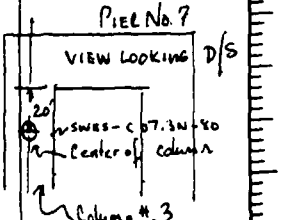
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
464.7	0.0		1" x 1" STEEL			Run No. 1 15 Nov. 80
464.7	1.0		½" REBAR			WL — Run 3.5
			¼" REBAR			Began 11.30 Rec 3.5
				100%	Box 1	End 3.30 Loss —
464.7	2.0		CONCRETE:			Time 240 min Gain —
						Drl time 135 min
						Hyd press —
						Water press MED
						RPM 300
						Drl Action Smooth
						Water ret
						Brown
						Remarks
						DRILL BINDING UP AT DIFFERENT DEPTHS
464.7	3.0		HAIRLING CRACK (1/16" TO ¼" MAX WIDTH)			
			1" x 1" REBAR			
			½" REBAR			
			RUN No 1 RQD = 100%		35	

CONCRETE: PHYSICAL PROPERTIES SAME. CONDITION APPEARS GOOD, LARGE CRACK AT 2.5' TO 3.5' WAS FOUND ON CORE. VERY LITTLE REACTION PRODUCT WAS VISIBLE.

DIAMOND BIT No
81PC 72
81PC 175

LEGEND
△ - CONCRETE
MB - MACHINE BROKE
NB - NATURAL BREAK

LOCATION



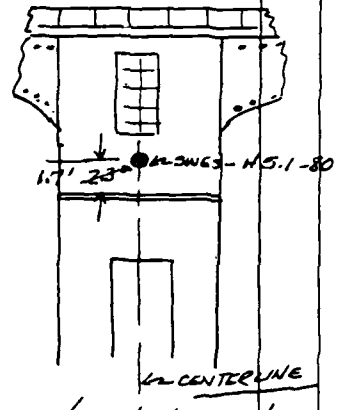
ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. SWES-HS1-80

DRILLING LOG | Division: St. Louis, Mo | Installation: Lock & Dam No 24 | Sheet 1 of 1 Sheets

1. Project: Lock & Dam No. 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: CEWES
4. Hole No. (As shown on drawing title and file number): SWES-HS1-80
5. Name of Driller: E. Mc Namara
6. Direction of Hole: ☐ Vertical ☒ Inclined 90° Deg. From Vert.
7. Thickness of Overburden: 0.2'
8. Depth Drilled into Rock: 1.0'
9. Total Depth of Hole:
10. Size and Type of Bit: 6 x 6 1/2"
11. Datum for Elevation Shown (MSL or Mean): MSL
12. Manufacturer's Designation of Drill: Electric - Core Drill
13. Total No. of Overburden Samples Taken: Disturbed: Undisturbed:
14. Total Number Core Boxes: ONE
15. Elevation Ground Water:
16. Date Hole: Started 1 Dec 80 Completed 1 Dec 80
17. Elevation Top of Hole: 471.6 - Ceneu
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Quay L. Dunn

Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) (g)
473.3	0.0		Concrete - Good Condition - Rebar - ½" - Run No 1	RQD = 100%		
473.3	1.0		Location - Pier No 5			



Remarks:
WL —
Began 10:30
End 10:45
Time 15 min
Drl time 10 min
Hyd press —
Water press Head
RPM 300
Drl Action Smooth
Water ret Brown
Rec 0.7'
Loss —
Gain —
Rur. 0.7'

LEGEND

C.T. - CONCRETE
MB - MACHINE BREAK
NB - NATURAL BREAK

DIAMOND BITS
79PB689

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. SWES-C09.15-80

DRILLING LOG — Division: St. Louis, Mo. — Installation: Lock & Dam No. 24 — Sheet 1 of 1 sheets

1. Project: Lock & Dam No. 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: CE WES
4. Hole No. (As shown on drawing title and file number): SWES-C09.15-80
5. Name of Driller: A McNamara
6. Direction of Hole: ☐ Vertical ☑ Inclined 90° deg. from vert.
7. Thickness of Overburden:
8. Depth Drilled into Rock: 3.50'
9. Total Depth of Hole:
10. Size and Type of Bit: 6" See Below
11. Datum for Elevation Shown (MSL or USC): MSL
12. Manufacturer's Designation of Drill: Electric – Core Drill
13. Total No. of Overburden Samples Taken: Disturbed: — Undisturbed: —
14. Total Number Core Boxes: One
15. Elevation Ground Water: —
16. Date Hole: Started 14 November 80 Completed 14 November 80
17. Elevation Top of Hole: 468.0 ft
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Lloyd B. Jones

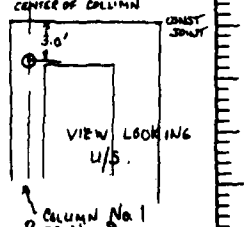
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, etc.; if significant) (g)
468.0	0					WL — 14 Nov 80 Run 3 5
		NB	Weathered - Poor Condition			Began 11 00 Ren 3 5
		NB				End 3 00 Loss —
468.0	1.0					Time 240 min Gain —
						Drl time 200 min
						Hyd press —
					Box 1	Water press MED
						RPM 300
			½" Reak	100%		Drl Action Smooth
			Acc cracked-			Water rot Brown
468.0	2.0	NB	Concrete.			Remarks
			Δ Δ Δ			
468.0	3.0	NB	Δ			
			— Reak - 1"x1"			
		NB	Run 1 RQD: 85.7%		3.50	

Concrete. Physical Properties same as other W.E.S Borings. Intense weathering on upper surface (0.0–2.0') of core. Numerous hairline cracks and breaks are found along with moderate reaction product on surfaces. Concrete is in Poor Condition —

Diamond Bit No.
81PC174
81PC172

LEGEND
- Concrete
- Hairline crack
- MB - Machine Break
- NB - Natural Break

Location



ENG FORM 1836 MAR 71 — Previous editions are obsolete. (Translucent) — Project — Hole No.

Hole No. SWGS-C09.1W-80

DRILLING LOG

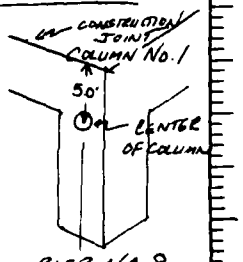
DIVISION: St Louis Mo
INSTALLATION: Lock & Dam No. 24
SHEET 1 OF 1 SHEETS

1. PROJECT: Lock and Dam No 24
2. LOCATION (Coordinates or Station): See Below
3. DRILLING AGENCY: C.E. W.E.S.
4. HOLE NO. (As shown on drawing title and file number): SWGS-C09.1W-80
5. NAME OF DRILLER: A McNamara
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN:
8. DEPTH DRILLED INTO ROCK: 3.05'
9. TOTAL DEPTH OF HOLE:
10. SIZE AND TYPE OF BIT: 6" See Below
11. DATUM FOR ELEVATION SHOWN (MSL or MLW): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Electric - Core Drill
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
14. TOTAL NUMBER CORE BOXES: One
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 14 November 80 COMPLETED 14 November 80
17. ELEVATION TOP OF HOLE: 4660
18. TOTAL CORE RECOVERY FOR BORING: 100%
19. SIGNATURE OF INSPECTOR: Lloyd B Dunbar

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc.; if significant)
4660	00		NB NB ¼"-⅜" Rebar Run No 1 RQD-0 0%			14 NOV 80 WL — Run 8.35 Began 3:45 Rec 0.35 End 4 00 Loss — Time 15 min Gain — Drl time 15 min Hyd press — Water press MED RPM 300± Drl Action Smooth Water ret Brown Remarks Blocked off on Rebar
4660	10		Concrete	160/	Box 1	
4660	20		NB Rebar 1" Rebar ½" Rebar 1"x1"			
4660	30		Run No 2 RQD- 88 8%	3.05'		WL — Run 2.7 Began 4:05 Rec 2.7 End 5:10 Loss — Time 65 min Gain — Drl time 65 min Hyd press — Water press MED RPM 300± Drl Action Smooth Water ret Brown Remarks

Concrete Physical Properties the same as other W.E.S. Boring — color, agg.. etc. Condition of concrete appears good No hairline cracks, slight reaction product, along with v. high RQD — Break at 2.5 was done in handling.

LOCATION



Diamond Bit No
81RC172
81PC175

LEGEND

- Concrete
- Hairline Crack
- MB · Machine Break
- NB · Natural Break

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. SWES-C09.2N-80

DRILLING LOG

DIVISION: St Louis, Mo	INSTALLATION: Lock + Dam No 24
SHEET 1 OF 1 SHEETS	
1. PROJECT: Lock + Dam No 24	10. SIZE AND TYPE OF BIT: 6 1/4" - NX 79 PW 0432
2. LOCATION (Coordinates or Station): See Below	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: CE WES	12. MANUFACTURER'S DESIGNATION OF DRILL: Acker
4. HOLE NO (As shown on drawing title) and file number: SWES-C09.2N-80	13. TOTAL NO OF OVERBURDEN SAMPLES TAKEN: DISTURBED ____ UNDISTURBED ____
5. NAME OF DRILLER: A McNamara	14. TOTAL NUMBER CORE BOXES: ONE
6. DIRECTION OF HOLE: ☐ VERTICAL ☑ INCLINED 90° DEG. FROM VERT	15. ELEVATION GROUND WATER: ____
7. THICKNESS OF OVERBURDEN: /	16. DATE HOLE: STARTED 12 November 80 COMPLETED 12 November 80
8. DEPTH DRILLED INTO ROCK: 3.6'	17. ELEVATION TOP OF HOLE: 469.2 ft
9. TOTAL DEPTH OF HOLE:	18. TOTAL CORE RECOVERY FOR BORING: 100%
	19. SIGNATURE OF INSPECTOR: Joseph B Ford

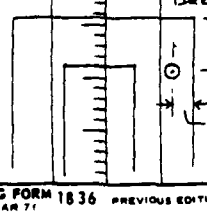
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Descriptions)	% CORE RECOVERY	BOX OR SAMPLE NO	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
469.2	0		NB 1" REBAR (1"x2") RUN #2 RQD=0.0%	100%		RUN #1 12 November 80 WL — Run 0.5 Began 12 15 Rec 0.5 End 1 20 Loss — Time 65 min Gain — Drl time 60 min Hyd press 100 PSI Water press MED RPM 80 I Drl Action Smooth Water ret Color Brown Remarks BLOCKED OFF ON REBAR
469.2	10		NB 1/4 REBAR - PITTED & OXIDIZED SLIGHT CRACK 45° 70% and broken NB 45° at 90° to 1/4 break RUBBLE, pieces from 1/2" to 2" in size, broken inplace	100%	BOX 1	
469.2	20		MB RUBBLE RUN #2 RQD=0.0% NB-AR 1/4" REBAR	100%		RUN #2 WL — Began 1 35 Run 3.75' End 3 40 Rec 2.25' Time 125 min Loss — Drl time 120 min Gain — Hyd press 100 PSI Water press MED RPM 80 I Drl Action Smooth Water ret Color Brown Remarks BLOCKED OFF
469.2	30		RUN #3 RQD=100%		BOX 1 36	RUN #3 WL — Began 4 00 Run 0.85 End 5 20 Rec 0.85 Time 80 min Loss — Drl time 75 min Gain — Hyd press 100 PSI Water press MED RPM 80 I Drl Action Smooth Water ret Color Brown Remarks

NOTE: LOST SOME WATER THROUGH CRACK ON WEST EDGE OF PIER AT APPROXIMATELY 110' — CAUSE OF CORROSION ON 1¼" REBAR.

LEGEND

- CONCRETE
- BROKEN UP - Too Small to Log + No Orientation of Pieces.
- MB - MACHINE BREAK
- NB - NATURAL BREAK

LOCATION



CONCRETE - VERY POOR CONDITION

INTENSE WEATHERING WITH REACTION PRODUCT FOUND ON ENTIRE SURFACE OF DRILLED CORE — CORE CAME OUT AS RUBBLE FOR MAJORITY AS SHOWN ABOVE — STEEL WAS OXIDIZED AND PITTED SEE ABOVE FOR LOCATION

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT ____ HOLE NO. ____

Hole No. 36 CS-CL-9 45-6c

DRILLING LOG | Division: St. Louis, Mo | Installation: Lock + Dam No 24 | Sheet 1 of 1 sheets

1. Project: Lock + Dam No 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: C.E.W.E.S.
4. Hole No (As shown on drawing title and file number): SNED-CO9 45-80
5. Name of Driller: A McNamara
6. Direction of Hole: ☐ Vertical ☐ Inclined 90° Deg. from vert.
7. Thickness of Overburden: /
8. Depth Drilled into Rock: 3.5
9. Total Depth of Hole:
10. Size and Type of Bit: 6" - See Below
11. Datum for Elevation Shown (MSL or MLW): MSL
12. Manufacturer's Designation of Drill: Electric - Core Drill
13. Total No. of Overburden Samples Taken: Disturbed / Undisturbed
14. Total Number Core Boxes: ONE
15. Elevation Ground Water:
16. Date Hole: Started 14 November 80 Completed 19 November 80
17. Elevation Top of Hole: 465.7
18. Total Core Recovery for Boring: 100 %
19. Signature of Inspector: Gayle B Wanless

Elevation	Depth	Legend	Classification of Materials (Descriptions)	Core Recovery	Box or Sample No.	Remarks
465.7	0.0		NB-MB Run No 2 RQD: 00%			Run 1 19 Nov 80
465.7	1.0		Concrete	100%	Box 1	WL — Run 3.25 Began 2:50 Rec 3.25 End 3:05 Loss — Time 15 min Gain — Drl time 15 min Hyd press — Water press MED RPM Buoy Drl Action Smooth Water ret Brown Remarks Rusteel
465.7	2.0		NB			
465.7	3.0		NB-MB Run No 2 RQD: 100%		3.50'	Run 2 WL — Run 3.25 Began 3:10 Rec 3.25 End 4:05 Loss — Time 55 min Gain — Drl time 55 min Hyd press — Water press MED RPM Buoy Drl Action Smooth Water ret Brown Remarks

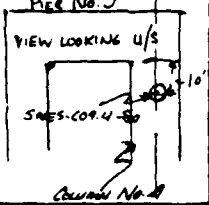
Concrete Physical Properties Same

Fair condition - little to no reaction product with no oxidation on steel's surface. Ends are slightly weathered.

Diamond Bits
81RC176
81RC178

Legend
- Concrete
- Hairline Crack
- MB - Machine Break
- NB - Natural Break

Location: Center of Column



ENG FORM 1836 MAR 71 Previous editions are obsolete (Translucent) | Project | Hole No

Hole No. SNCS-C09-3N-B

DRILLING LOG — Division: St Louis, Mo — Installation: Lock + Dam No. 24 — Sheet 1 of 1 Sheets

1. Project: Lock + Dam No. 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: CENES
4. Hole No. (As shown on drawing title and file number): SNCS-C09-3N-80
5. Name of Driller: A McNamara
6. Direction of Hole: ☐ Vertical ☒ Inclined 90° deg. from vert.
7. Thickness of Overburden: /
8. Depth Drilled into Rock: 3.5
9. Total Depth of Hole: /
10. Size and Type of Bit: See Below — 6"
11. Datum for Elevation Shown (MSL): MSL
12. Manufacturer's Designation of Drill: Elcork - Core Drill
13. Total No. of Overburden Samples Taken: Disturbed — Undisturbed
14. Total Number Core Boxes: One
15. Elevation Ground Water: —
16. Date Hole: Started 19 November 80 — Completed 19 November 80
17. Elevation Top of Hole: 467.3 ft.
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Joseph B Dunbar

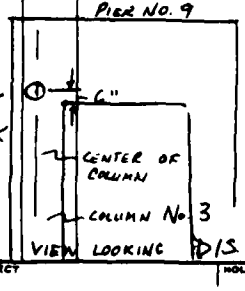
Elevation	Depth	Legend	Classification of Materials (Description)	Core Recovery	Box or Sample No.	Remarks
467.3	00		1½" Base Rock			
			Run No. 1 RQD=0.0%			Run No 1 19 Nov 80
			Steel 1" x 1"			AL Run 0.4'
			Concrete Broken up around Steel			Began 1005 Rec 0.4
467.3	10		Hairline Crack			End 1023 Loss —
			Rebar			Time 20 min Gain —
				100%	Box 1	Drl time 18 min
467.3	20		Rebar			Hyd press —
						Water press MED
						RPM 600
			Concrete			Drl Action Smooth
467.3	30		Steel - 1" x 1"			Water ret Brown
			Rebar Run No. 2 RQD=90%	3.50'		Remarks Rebar
						Run No 2
						AL — Run 3.1
						Began 1835 Rec 3.1
						End 1230 Loss —
						Time 115 min Gain —
						Drl time 15 min
						Hyd press —
						Water press MED
						RPM 700
						Drl Action Smooth
						Water ret Brown
						Remarks

Concrete: Physical Properties the same as other W.E.S. Borings. Condition is poor grading towards fair at centr of column. Ends are weathered with slight reaction product. Steel appears unoxidized —

Diamond Bits
81RC173
81PC169

Legend
[a] · Concrete
[---] · Hairline Crack
NB · Natural Break
MB · Machine Break

Location



ENG FORM 1836 MAR 71 Previous editions are obsolete (Translucent) — Project — Hole No.

Hole No. SWES-C09.2N-50

DRILLING LOG	DIVISION	INSTALLATION: Lock & Dam No 24	SHEET 1 OF 1 SHEETS
1. PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (GS or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE STARTED / COMPLETED	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING %	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc.; if applicable) g
4692	00		CLOSED OPEN - CRACKS			
4692	10		HAIRLING - CLOSED			
4692	20		AS VIEWED INSIDE BORING —			

ENG FORM 1836 MAR 77 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. SWGS-C13-3N-60

DRILLING LOG — DIVISION: St. Louis Mo. — INSTALLATION: Lock and Dam No. 24 — SHEET 1 OF 1 SHEETS

1. PROJECT: Lock + Dam No. 24
2. LOCATION (Coordinates or Station): See Below
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): SWGS-C13.3N-60
5. NAME OF DRILLER: D McNamara
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN:
8. DEPTH DRILLED INTO ROCK: 9.55
9. TOTAL DEPTH OF HOLE:
10. SIZE AND TYPE OF BIT: 6 & 6 1/2" - See Below
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): M.S.L.
12. MANUFACTURER'S DESIGNATION OF DRILL: Electric - Core Drill
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED:
14. TOTAL NUMBER CORE BOXES: ONE
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 21 Nov 60 COMPLETED 21 Nov 60
17. ELEVATION TOP OF HOLE: 460.0' Center Box, No
18. TOTAL CORE RECOVERY FOR BORING: 100%
19. SIGNATURE OF INSPECTOR: Joseph B Parker

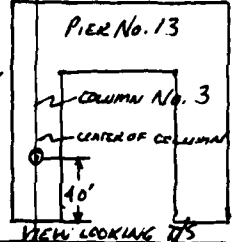
ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	CORE RECOV. ERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
460.0	00		1/2" Rebar			Run No. 1 21 Nov 60
			STEEL			#L Run 3.55
						Began 9-1:00 Rec 3.55
460	10					End 7:45-10:45 Loss —
			CONCRETE SAME			Time 110 MIN Gain —
				100%	Box 1	Drl time 120 MIN
						Hyd press —
460	20					Water press MED
						RPM 300 t
						Drl Action Smooth
						Water ret Brown
			NB			Remarks Drill Left Bending Up 3 Overnothing -
			1/2" Rebar			
460	30					
			STEEL			
			RUN No. 1 RQD = 100%		355	

CONCRETE - PHYSICAL PROPERTIES SAME AS OTHER WES BORINGS. CONDITION OF CONCRETE IS GOOD - VERY LITTLE TO NO REACTION PRODUCT AND NO SIGNS OF WEATHERING. SLIGHT OXIDATION OF STEEL AT 0.35 FT

DIAMOND BIT
79RN429
79RN430

LEGEND
- CONCRETE
- HAIRLINE CRACK
- MB · MACHINE BREAK
- NB · NATURAL BREAK

LOCATION



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT — HOLE NO.

Hole No. SWES-C13.2N6

DRILLING LOG

DIVISION: St Louis, Mo	INSTALLATION: Lock & Dam #24
SHEET 1 OF , SHEETS	
1. PROJECT: Lock & Dam #24	10. SIZE AND TYPE OF BIT: 6 - See Below
2. LOCATION (Coordinates or Station): See Below	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL: Acker
4. HOLE NO. (As shown on drawing title and file number): SWES-C13.2NBO	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —
5. NAME OF DRILLER: A. McNamara	14. TOTAL NUMBER CORE BOXES: ONE
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.	15. ELEVATION GROUND WATER: —
7. THICKNESS OF OVERBURDEN: —	16. DATE HOLE: STARTED 11 November 80 COMPLETED 12 November 80
8. DEPTH DRILLED INTO ROCK: 3.5	17. ELEVATION TOP OF HOLE: 462.0 Center Boring
9. TOTAL DEPTH OF HOLE: —	18. TOTAL CORE RECOVERY FOR BORING: 100%
	19. SIGNATURE OF INSPECTOR: [signature]

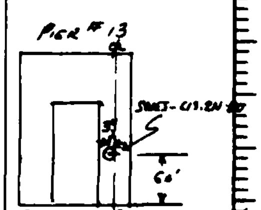
ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
462.0	0.0	Δ	3/4" Rebar; Run #1	100%		Run #1 11 November 80; WL —; Began 12:09; End 1:20; Time 71 min; Run 0.35'; Rec 0.35; Loss —; Gain —; Drl time 71 min; Hyd press 100 PSI; Water press MED; RPM 705; Drl Action Smooth; Water ret Brown; Remarks: Took up impregnated bit on end of rebar
			1/4" of Rebar - 1"x2" Steel			
462.0	1.0	Δ	1/4" Rebar		Box 1	
462.0	2.0	Δ	Concrete	100%		
462.0	3.0	Δ	1/4" Rebar; Run #2 RQD - 100%		3.5'	Run #2 113 12 November 80; WL —; Began 2:30-5; End 7:50-10:30; Time 340 min; Run 3.15; Rec 3.15; Loss —; Gain —; Drl time 340 min; Hyd press 100 PSI; Water press MED; RPM 803; Drl Action Smooth; Water ret Brown; Remarks

CONCRETE - Grey Brown in color, natural aggregate (size and shape as indicated in other WES borings), steel appears un-oxidized and condition of concrete from this column is very good. Little to no R.P. and with no other signs of weathering visible.

DIAMOND BITS
79PB690
79PN0432

LEGEND
Δ - Concrete
MB - Machine Break
NB - Natural Break
RP - Reaction Product

LOCATION



Center of boring was offset 3" to miss rebar

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. SAKS-C16.1W-80

DRILLING LOG | Division: St. Louis, Mo. | Installation: Lock & Dam No. 24 | Sheet 1 of 1 sheets

1. Project: Lock & Dam # 24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: C.E.W.E.S.
4. Hole No. (As shown on drawing title) and file number: SAKS-C16.1W-80
5. Name of Driller: D McNamara
6. Direction of Hole: ☐ Vertical ☑ Inclined 90° deg. from vert.
7. Thickness of Overburden:
8. Depth Drilled into Rock: 3.1'
9. Total Depth of Hole:
10. Size and Type of Bit: 6" - See Below
11. Datum for Elevation Shown (Ft. or M.S.L.): MSL
12. Manufacturer's Designation of Drill: Electric - Core Drill
13. Total No. of Overburden Samples Taken: Disturbed: Undisturbed:
14. Total Number Core Boxes: One
15. Elevation Ground Water:
16. Date Hole: Started 13 November 19 80 Completed 13 November 19 80
17. Elevation Top of Hole: 466.9 ft
18. Total Core Recovery for Boring: 100% %
19. Signature of Inspector: Joseph B Brown

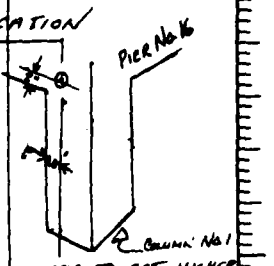
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	Core Recov. Ratio (e)	Box or Sample No. (f)	Remarks (Drilling rate, water loss, depth of weathering, etc., if significant) (g)
466.9	0.0		Run #1 RQD: 00%			Run #1 13 November 80 WL — Run 0.35 Began 1:45 Rec 0.35 End 2.00 Loss — Time 15 min Gain — Drl time 15 min Hyd press — Water press MED RPM 300 rpm Drl Action Smooth Water ret Brown Remarks Cranked bits - Rebar
466.9	1.0		⅞"-1" Rebar			
466.9	1.0		⅞"-1" Rebar			
466.9	2.0		Concrete	100%	Box 1	
466.9	3.0		½" 1½"x1" Run #2 RQD: 100%	3.1		Run #2 WL — Began 2.45-2.55 Run 2.75' End 4.60-4.70 Loss — Time 60 min Gain — Drl time 60 min Hyd press — Water press MED RPM 300 Drl Action Smooth Water ret Brown Remarks Burned up electric motor Replaced motor with spare

Concrete: Physical Properties same as other borings — Agg. color, etc. Condition of concrete appears to be good. Very little to no reaction product and steel surfaces appears unoxidized.

Diamond Bits
81AC176
81AC179

Legend
- Concrete
- Broken up - to small to log
- MB - Machine Break
- NB - Natural Break

Location



Unable to get higher due to superstructure of bridge - chain hoist

ENG FORM 1836 MAR 71 Previous editions are obsolete. (TRANSLUCENT)

Project: Hole No.

Hole No. SWES-C16.15-80

DRILLING LOG

Division: St Louis, Mo	Installation: Lock & Dam #24
Sheet: 1 of 1 Sheets	
1. Project: Lock & Dam #24	10. Size and Type of Bit: 6" See Below for Nos
2. Location (Coordinates or Station): See Below	11. Datum for Elevation Shown (USGS or Mean): MSL
3. Drilling Agency: CE WES	12. Manufacturer's Designation of Drill: Acker
4. Hole No. (As shown on drawing title and file number): SWES-C16.15-80	13. Total No. of Overburden Samples Taken: Disturbed — Undisturbed —
5. Name of Driller: A McNamara	14. Total Number Core Boxes: ONE
6. Direction of Hole: ☐ Vertical ☒ Inclined 90 deg. from vert.	15. Elevation Ground Water: —
7. Thickness of Overburden: —	16. Date Hole: Started 8 November 80 Completed 10 November 80
8. Depth Drilled into Rock: 3.6'	17. Elevation Top of Hole: 475.45 - Control Boring
9. Total Depth of Hole:	18. Total Core Recovery for Boring: 100.0 %
	19. Signature of Inspector: Cheryl B. Bunker — 468.45

Elevation	Depth	Legend	Classification of Materials (Description)	% Core Recovery	Box or Sample No.	Remarks
475.45	0.0					Run #1 8 November 80
		NB	O.C - 1.5' & 2.5 - 3.6' HAIRLINE CRACKS DUE TO FROST DAMAGE - FREEZE THAW			#L Run 1.9
						Began 8:00 Rec 0.4
						End 4:50 Loss 1.5
						Time 168 min Gain —
475.45	1.0	Δ	- Rebar 2"x1" Concrete	22.2%	Box 1	Drl time 160 min
		NB	3/8" Rebar			Hyd press 50 to 80 PSI
		Δ				Water press Low to Med
		Δ	Run #1 RQD: 78.9%			RPM 50 to 70 I
						Drl Action Smooth
						Water ret Brown
475.45	2.0	Δ				Remarks CHANGED BITS
		Δ	- Rebar - 2"x1" Concrete		Box 1	Run #2 10 November 80
		Δ	½" Copper Rebar	18.1%		#L Run 1.7
475.45	3.0					Began 8:00 Rec 3.2
		NB	- ¾" Rebar			End 11:30 Loss —
			Run #2 RQD: 82.3%		3.6	Time 190 min Gain 1.8'
						Drl time 190 min
						Hyd press 80 PSI
						Water press Low & Med
						RPM 70 I
						Drl Action Smooth
						Water ret Brown
						Remarks

CONCRETE: PHYSICAL PROPERTIES ARE SAME AS ENCOUNTERED IN OTHER BORINGS (AGGREGATE, COLOR OF CONCRETE, ETC.)
CONDITION OF CONCRETE IS POOR. INTENSE WEATHERING [redacted] WAS FOUND IN THE CONCRETE. NUMEROUS HAIRLINE CRACKS WITH REACTION PRODUCT AND REACTION RIMS ON THE AGGREGATE WERE VISIBLE. STEEL SURFACES WERE NOT OXIDIZED WHERE VISIBLE. - BOTH STEEL AND COPPER REBAR WAS ENCOUNTERED

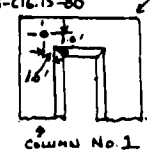
DIAMOND BIT
81PC177
81PC170

LEGEND

- Δ Concrete
- Hairline Cracks
- MB Machine Break
- NB Natural Break

LOCATION — Piece #16

SWES-C16.15-80



Column No. 1
View looking U/S

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT — HOLE NO.

Hole No. SLWES C16.3N-80

DRILLING LOG | Division: St Louis, Mo | Installation: Lock & Dam #24 | Sheet 1 of 1 Sheets

1. Project: Lock & Dam #24
2. Location (Coordinates or Station): See Below
3. Drilling Agency: CEWES
4. Hole No. (As shown on drawing title) and Site number: SLWES C16.3N-80
5. Name of Driller: A McNamara
6. Direction of Hole: ☐ Vertical ☒ Inclined 90° Deg. from vert
7. Thickness of Overburden: —
8. Depth Drilled into Rock: 35'
9. Total Depth of Hole: 35'
10. Size and Type of Bit: 4" - No. - 79PW0432
11. Datum for Elevation Shown (USGS or MSL): MSL
12. Manufacturer's Designation of Drill: Acker
13. Total No. of Overburden Samples Taken: Disturbed — Undisturbed —
14. Total Number Core Boxes: One
15. Elevation Ground Water: —
16. Date Hole: Started 10 November 80 Completed 11 November 80
17. Elevation Top of Hole: 426.9 ± (Center of Hole)
18. Total Core Recovery for Boring: 100%
19. Signature of Inspector: Joseph B. Tenley

Elevation	Depth	Legend	Classification of Materials (Description)	% Core Recovery	Box or Sample No.	Remarks
475.45	0.0		REAR - 2' x 1' NB NB			Run #1 Rm 3.50 Began 3.30-5.30 Rec 3.50 End 7.45-11.15 Loss — Time 330 min Gain — Drl time 315 min Hyd press 80 TO 100 BI Water press MED RPM 70± Drl Action Smooth Water ret Brown Remarks
475.45	1.0		— 1' VISUAL EXTENT OF FREEZE-THAW DAMAGE CONCRETE	100%	Box 1	
475.45	2.0					
475.45	3.0		Run #1 RQD: 77%			

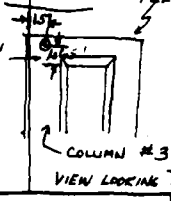
CONCRETE: PHYSICAL PROPERTIES SAME AS OTHER BORINGS (COLOR, AGGREGATE, ETC)
CONDITION OF CONCRETE IS FAIR.
ONLY THE FIRST FOOT IS INTENSELY WEATHERED AND REMAINING CONCRETE APPEARS TO BE IN GOOD CONDITION. NUMEROUS HAIRLINE CRACKS, BREAKS, AND MOD. REACTION PRODUCT IS VISIBLE IN THE FIRST FOOT, STEEL LOOKS TO BE IN GOOD CONDITION, THERE IS NO OXIDATION FOUND ON STEEL'S SURFACE (Bar @ 0.35')

DIAMOND BIT
79PW0432

LEGEND

- Concrete
- Hairline Cracks
- MB Machine Break
- NB Natural Break

LOCATION



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO

Hole No. SWES-C-16.2N-80

DRILLING LOG | DIVISION: St. Louis, Mo | INSTALLATION: Lock & Dam #24 | SHEET 1 OF 1 SHEETS

1. PROJECT: Lock & Dam #24
2. LOCATION (Coordinates or Station): Mile Below
3. DRILLING AGENCY: C.E.W.E.S.
4. HOLE NO. (As shown on drawing title) and file number: SWES-C-16.2N-80
5. NAME OF DRILLER: A. McMaynard
6. DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK 3.5
9. TOTAL DEPTH OF HOLE

10. SIZE AND TYPE OF BIT 6"-5.5" Rotary
11. DATUM FOR ELEVATION SHOWN (MSL or USC&GS): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED ___ UNDISTURBED ___
14. TOTAL NUMBER CORE BOXES: ONE
15. ELEVATION GROUND WATER ___
16. DATE HOLE: STARTED 10 November 80 COMPLETED 13 November 80
17. ELEVATION TOP OF HOLE: 467.45'
18. TOTAL CORE RECOVERY FOR BORING: 100%
19. SIGNATURE OF INSPECTOR: Joseph B. Strahan

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc.; if applicable)
467.45	0.0		¾" Rebar } HAIRLINE CRACK			Run #1 10 November 80
			NB.			WL — Rig 0.9
			Run #1 RQD: 0.0%		Box 1	Began 12:45 Rec 0.3
467.45	1.0		Steel Rebar			End 1:35 Los 4.0
			NB NB NB			Time 50 min Gain —
			Concrete			Drl time 50 min
					Box 1	Hyd press 60
467.45	2.0					Water press Low to MED
			Bond broke in half - ¼" sq.			RPM 70
			~ V. Slight crack			Drl Action Smooth
						Water ret Brown
467.45	3.0		NB ¾" Rebar } HAIRLINE CRACKS			Remarks Stripped Head on Core Bbl.
			Run #2 RQD: 80%		3.5	Run #2 13 November 80
						WL — Run 2.6'
						Began 8:30 Rec 3.0'
						End 10:45 Loss —
						Time 135 min Gain 0.4'
						Drl time 135 min
						Hyd press 75 PSI
						Water press MED
						RPM 75
						Drl Action Smooth
						Water ret Brown
						Remarks

Concrete: Weathered at ends with numerous hairline cracks, moderate reaction product, and natural breaks - center of core improves in condition but still noticeable is slight amount of reaction product. Steel where exposed does not appear oxidized or corroded. - Ends are in poor condition while center is in fair condition.

Diamond Bit
81PC174
81PC176

LEGEND
C - Concrete
MB - Machine Break
NB - Natural Break
Hairline Crack

LOCATION
18'
Pool No. 16
SWES-C-16.2N-80
Even with top of arch
Column No. 3
View looking D/S

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

APPENDIX C: REPORT OF PETROGRAPHIC EXAMINATION OF CONCRETE CORES

Corps of Engineers, USAE Waterways Experiment Station	Concrete Report	Structures Laboratory P. O. Box 631 Vicksburg, Mississippi
Project Investigation of Concrete Deterioration, Lock and Dam 24		Date 13 March 1981 GSW

Samples

1. Portions of concrete from five cores from Lock and Dam No. 24 were selected for detailed petrographic examination. A general description of the 6-in.-diameter concrete cores is as follows:

Field Identification No.	Description
S WES-C16.2 N-80	Horizontal core into badly deteriorated concrete
S WES-C16.3 E-80	Horizontal core into moderately deteriorated concrete
S WES-C13.2 N	Horizontal core into good concrete
S WES-P04.1	Vertical core into good concrete
S WES-P09.1	Vertical core into good concrete

Test procedures

2. The concrete cores that were examined represented different visual physical conditions of the concrete. Some portions of the concrete examined were deep interior concrete while other concrete represented the near surface material.

3. The appearance and condition of this concrete was compared to that of the concrete previously examined from the same structure in 1976[1] and 1978.[2] The current samples are more representative of the general condition of the concrete deterioration and the extent of the damage.

4. Twenty-five cores were examined megascopically to determine the overall homogeneity of the concrete. Portions of the concrete cores described earlier were selected for further examination.

5. Several pieces of core were sawed longitudinally. One of each pair of sawed surfaces was ground smooth and examined with a stereomicroscope.

6. The core surfaces were examined for signs of deleterious chemical reaction and/or physical degradation. Fresh fracture surfaces were also examined. A stereomicroscope was used as needed to aid in the examination.

7. Reaction products from interior concrete surfaces and exudation from core surfaces were examined as oil immersion mounts using a polarizing microscope.

8. A black substance coating a break in core S WES-P04.1 at about 12.5-ft depth was also examined. Acetone was used to remove the coating from the break surface before the concrete was examined.

Results

9. Concrete from core S WES-C16.2 N-80 represented severely deteriorated concrete. This concrete was highly fractured and tended to disaggregate easily during drilling and handling. The concrete from boring S WES-C16.3 E-80 represented moderately deteriorated concrete. This concrete contained a major longitudinal crack in the center of the core in which a white exudation is collecting on the exposed surface of the concrete. All other concrete cores represented intact concrete from both the interior and near surface concrete of the structure.

10. The concrete in all the cores examined contained gravel and sand of mixed composition. The maximum size coarse aggregate was about 1-1/2 in. The aggregate consisted of sandstone, quartz, chert, carbonate rock particles, dark fine-grained igneous rock particles, coarse-grained igneous rock particles, and some particles of ironstone. Chalcedony in chert particles was identified as the most common reactive aggregate material in this group of concrete cores. This finding is similar to the observations made in the two earlier reports.[1,2]

11. Some of the concrete contained pale yellowish brown (10 YR 6/2)[3] paste while the remainder of the concrete contained medium light gray (N6)[3] paste. There was no apparent physical difference between the different colored pastes. White alkali silica gel was present in both colors of paste.

12. The general deterioration consisted of parallel to subparallel cracking occurring parallel to the formed surface of the cores. These partings tended to be closely spaced near the outer surface of the concrete and were absent in the interior concrete. The photographs in Figure C1 are a set of pictures of core S WES-C16.2 N-80 drilled through a column on pier No. 16. Deterioration was present at both ends of this core while the central portion of it remained relatively intact.

13. Examination of ground surfaces indicated that this concrete was not air entrained. The concrete contained a few entrapped air voids but generally the concrete was dense and intact.

14. The maximum depth of deterioration was to a depth of 1.5 ft as found in core S WES-C16.2 N-80. Most of the deterioration was confined to the exterior 0.6 ft of concrete.

15. This concrete also tended to be saturated with white alkali-silica gel. This gel was present coating the cracks and as surface exudation. Some calcium hydroxide was also carried to surfaces in solution and deposited as white deposits. The alkali-silica gel ranged from a thick white to a clear material totally encasing the reactive aggregate and penetrating into the adjacent paste.

16. The black material coating the broken surface of core S WES-P04.1 at about 12.5 ft was a pliable black tar-like substance. The concrete beneath the coating was undisturbed. The coating appeared to have been put on the concrete as some sort of a bond breaker.

Conclusions

17. The lack of entrained air in this concrete caused the concrete to be susceptible to frost damage. The repeated freezing and thawing of the concrete while critically saturated has caused delamination of the concrete, especially near surfaces.

18. The opening of the concrete by frost action has accelerated the alkali-silica reaction. This deleterious chemical reaction has caused additional disaggregation of the frost-damaged concrete. The interior concrete shows slight indications of alkali-silica reaction, but has not caused any significant damage to the interior concrete.

References Cited

1. U. S. Army Engineer Waterways Experiment Station petrographic report dated 30 January 1976 to the U. S. Army Engineer District, St. Louis, subject: "Test and Examination of Concrete Cores from Lock and Dam 24 and Lock and Dam 25."

2. U. S. Army Engineer Waterways Experiment Station petrographic report dated December 1978 to the U. S. Army Engineer District, St. Louis, subject: "Examination of Concrete Cores from Lock and Dam 24."

3. The Rock Color Chart Committee, E. N. Goddard, Chm, "Rock Color Chart," 1975, The Geological Society of America, Boulder, Colo.

(a)

(b)

Figure C1. Opposite ends of core S WES-C16.2 N-80 drilled through a concrete column. The cracking is parallel to the formed surface and tends to go around the aggregate particles as well as through them

APPENDIX D: PHOTOGRAPHS SHOWING BURST PIPE

Photo 1. Fractured concrete wedge before removal. Column 3 on pier No. 16.

Photo 2. Concrete wedge removed exposing burst pipe, reinforcing steel, and wetted concrete.

Photo 3. Close-up of area shown in Photo 2. Notice burst pipe and softer concrete. Most all large aggregate show clean tensile failure surfaces.

P. to S. River surface atop of bridge support column. X to exhibit plate recessed lacing next to exhibit. Bearing plate seen in upper left of photograph. Dirt on river side of bottom chord exhibit and plate, as is typical.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Stowe, Richard L.
Condition survey repair and rehabilitation Lock and Dam No. 24, Mississippi River / by Richard L. Stowe, Henry T. Thornton, Jr. (Structures Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.
90 p. in various pagings, 46 p. of plates : ill. ; 27 cm. -- (Miscellaneous paper / U.S. Army Engineer Waterways Experiment Station ; SL-81-21)
Cover title.
"August 1981."
"Prepared for U.S. Army Engineer District, St. Louis."
Final report.
Bibliography: p. 33.

1. Concrete dams. 2. Concrete research. 3. Locks (Hydraulic engineering). 4. Mississippi River. I. Thornton, Henry T., Jr. II. United States. Army.

Stowe, Richard L.
Condition survey repair and rehabilitation : ... 1981.
(Card 2)

Corps of Engineers. St. Louis District. III. U.S.Army Engineer Waterways Experiment Station. Structures Laboratory. IV. Title V. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-81-21.
TA7.W34m no.SL-81-21